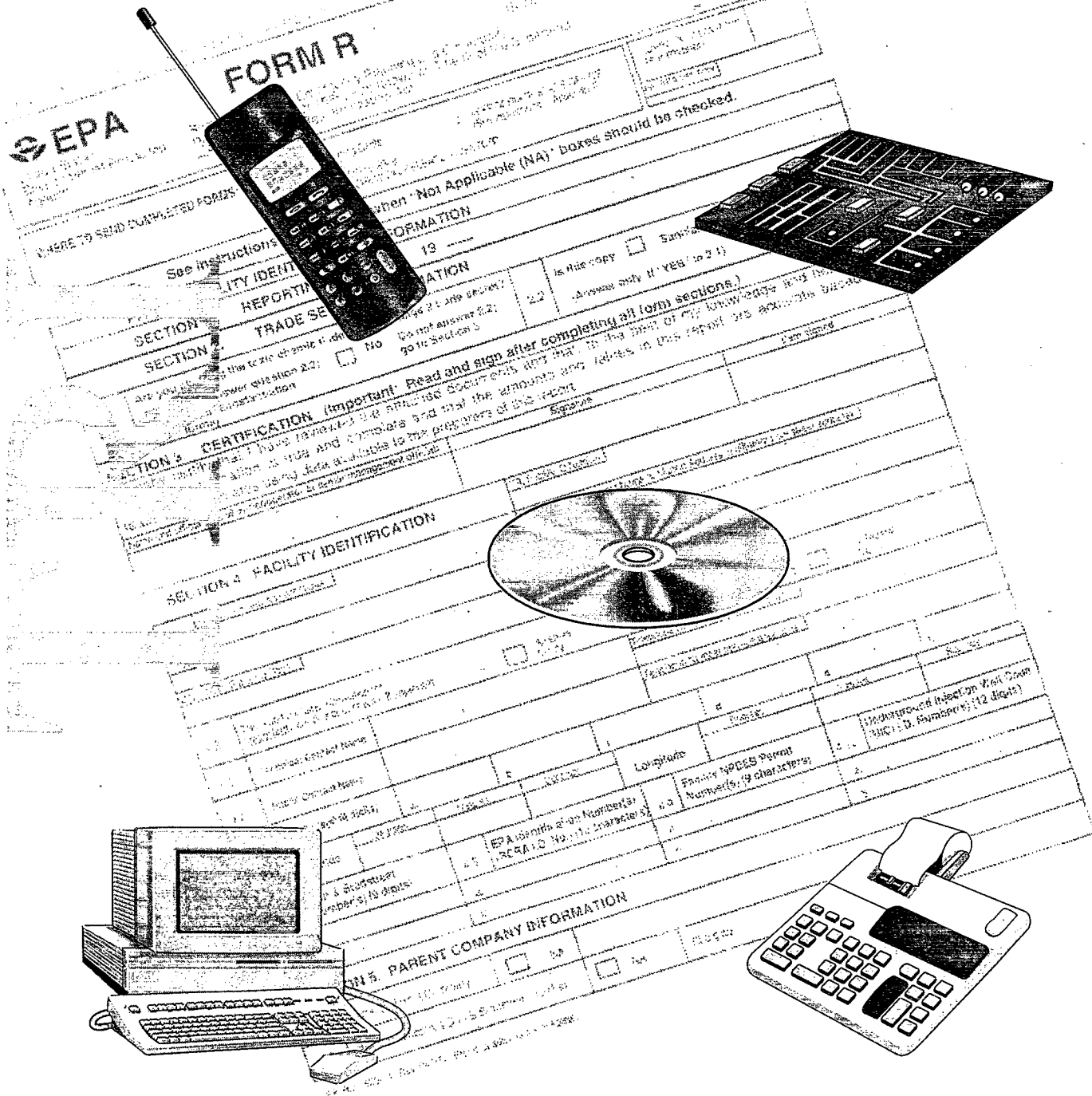




Emergency Planning and Community Right-To-Know Act Section 313 Reporting Guidance for Semiconductor Manufacturing



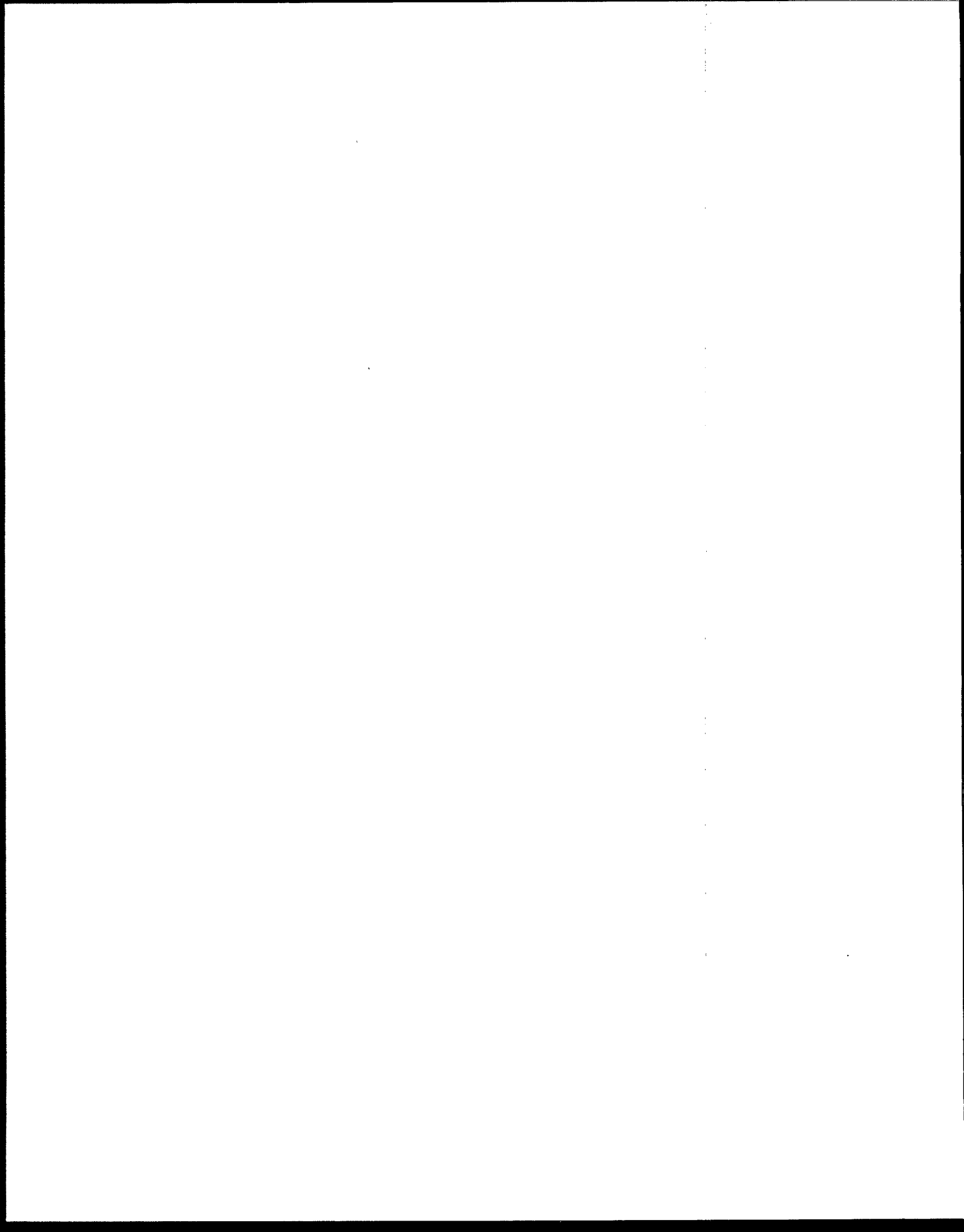


TABLE OF CONTENTS

	Page
ACKNOWLEDGMENT	vi
OVERVIEW	vii
CHAPTER 1 - INTRODUCTION	1-1
1.0 PURPOSE	1-1
1.1 Background on EPCRA Section 313 and PPA Section 6607	1-2
CHAPTER 2 - REPORTING REQUIREMENTS	2-1
2.0 PURPOSE	2-1
2.1 Must You Report?	2-2
2.2 SIC Code Determination	2-4
2.3 Number of Employees	2-6
2.4 Manufacturing, Processing, and Otherwise Use of EPCRA Section 313 Chemicals or Chemical Categories	2-7
2.5 Activity Categories	2-8
2.6 How Do You Report?	2-10
2.7 Form R	2-11
2.8 Alternate Threshold and Form A	2-12
2.9 Trade Secrets	2-13
2.10 Recordkeeping	2-14
CHAPTER 3 - EPCRA SECTION 313 CHEMICAL OR CHEMICAL CATEGORY ACTIVITY THRESHOLD DETERMINATIONS	3-1
3.0 PURPOSE	3-1
3.1 Step 1 - Identify Which EPCRA Section 313 Chemicals or Chemical Categories are Manufactured (Including Imported), Processed, or Otherwise Used	3-1
Qualifiers	3-4
3.2 Step 2. Identify the Activity Category and any Exempt Activities for Each EPCRA Section 313 Chemical	3-7
3.2.1 Concentration Ranges for Threshold Determination	3-11
3.2.2 Evaluation of Exemptions	3-12
3.2.2.1 <i>De Minimis</i> Exemption	3-13
3.2.2.2 Article Exemption	3-15
3.2.2.3 Facility-Related Exemption	3-17
Laboratory Exemption	3-17
3.2.2.4 Activity-Related Exemptions	3-17
3.2.3 Additional Guidance on Threshold Calculations for Certain Activities	3-19
3.2.3.1 Reuse Activities	3-19
3.2.3.2 Remediation Activities	3-20
3.2.3.3 Recycling Activities	3-21

TABLE OF CONTENTS (Continued)

	Page
3.3 Step 3. Calculate the Quantity of Each EPCRA Section 313 Chemical and Chemical Category and Determine Which Ones Exceed an Activity Threshold	3-21
4.0 PURPOSE	4-1
4.1 General Steps for Determining Release and Other Waste Management Activity Quantities	4-1
4.1.1 Step 1: Prepare a Process Flow Diagram	4-3
4.1.2 Step 2: Identify EPCRA Section 313 Chemicals and Chemical Categories and Potential Sources of Chemical Release and Other Waste Management Activities	4-3
4.1.3 Step 3: Identify Release and Other Waste Management Activity Types	4-4
4.1.4 Step 4: Determine the Most Appropriate Method(s) to Calculate the Estimates for Release and Other Waste Management Activity Quantities	4-16
4.1.4.1 Monitoring Data or Direct Measurement (code M)	4-18
4.1.4.2 Mass Balance (code C)	4-19
4.1.4.3 Emission Factors (code E)	4-21
4.1.4.4 Engineering Calculations (code O)	4-23
4.1.4.5 Estimating Release and Other Waste Management Quantities	4-24
4.2 Process Descriptions (Chemical Activities)	4-29
4.2.1 Photolithography	4-31
4.2.1.1 Step 1: Prepare Process Flow Diagram	4-32
4.2.1.2 Step 2: Identify Potential Sources of Chemical Release and Other Waste Management Activities	4-33
4.2.1.3 Step 3: Identify Release and Other Waste Management Activity Types	4-33
4.2.1.4 Step 4: Determine the Most Appropriate Method(s) to Calculate the Estimates for Release and Other Waste Management Activity Quantities	4-34
4.2.2 Thin Films	4-36
4.2.2.1 Step 1: Prepare Process Flow Diagram	4-37
4.2.2.2 Step 2: Identify Potential Sources of Chemical Release and Other Waste Management Activities	4-37
4.2.2.3 Step 3: Identify Release and Other Waste Management Activity Types	4-38
4.2.2.4 Step 4: Determine the Most Appropriate Method(s) to Calculate the Estimates for Release and Other Waste Management Activity Quantities	4-39
4.2.3 Etching	4-40
4.2.3.1 Step 1: Prepare Process Flow Diagram	4-41
4.2.3.2 Step 2: Identify Potential Sources of Chemical Release and Other Waste Management Activities	4-41

TABLE OF CONTENTS (Continued)

Page

4.2.3.3	Step 3: Identify Release and Other Waste Management Activity Types	4-42
4.2.3.4	Step 4: Determine the Most Appropriate Method(s) to Calculate the Estimates for Release and Other Waste Management Activity Quantities	4-42
4.2.4	Cleaning	4-43
4.2.4.1	Step 1: Prepare Process Flow Diagram	4-44
4.2.4.2	Step 2: Identify Potential Sources of Chemical Release and Other Waste Management Activities	4-44
4.2.4.3	Step 3: Identify Release and Other Waste Management Activity Types	4-45
4.2.4.4	Step 4: Determine the Most Appropriate Method(s) to Calculate the Estimates for Release and Other Waste Management Activity Quantities	4-48
4.2.5	Doping	4-48
4.2.5.1	Step 1: Prepare Process Flow Diagram	4-49
4.2.5.2	Step 2: Identify Potential Sources of Chemical Release and Other Waste Management Activities	4-50
4.2.5.3	Step 3: Identify Release and Other Waste Management Activity Types	4-50
4.2.5.4	Step 4: Determine the Most Appropriate Method(s) to Calculate the Estimates for Release and Other Waste Management Activity Quantities	4-51
4.2.6	Chemical Mechanical Planarization	4-51
4.2.6.1	Step 1: Prepare Process Flow Diagram	4-52
4.2.6.2	Step 2: Identify Potential Sources of Chemical Release and Other Waste Management Activities	4-52
4.2.6.3	Step 3: Identify Release and Other Waste Management Activity Types	4-53
4.2.6.4	Step 4: Determine the Most Appropriate Method(s) to Calculate the Estimates for Release and Other Waste Management Activity Quantities	4-53

Appendix A	TRI GUIDANCE RESOURCES
Appendix B	BASIC CALCULATION TECHNIQUES
Appendix C	GUIDANCE FOR REPORTING AQUEOUS AMMONIA
Appendix D	GUIDANCE FOR REPORTING SULFURIC ACID
Appendix E	LIST OF TOXIC CHEMICALS WITHIN THE WATER DISSOCIABLE NITRATE COMPOUNDS CATEGORY AND GUIDANCE FOR REPORTING
Appendix F	UNIT CONVERSION FACTORS

INDEX

LIST OF TABLES

	Page
2-1 SIC Codes Covered by EPCRA Section 313 Reporting	2-4
2-2 EPCRA Section 313 Chemicals and Chemical Categories Commonly Encountered in Semiconductor Manufacturing	2-8
2-3 Activity Categories	2-9
3-1 Reporting Thresholds	3-8
3-2 Definitions and Examples of Manufacturing Subcategories	3-9
3-3 Definitions and Examples of Processing Subcategories	3-10
3-4 Definitions and Examples of Otherwise Use Subcategories	3-11
3-5 EPCRA Section 313 Reporting Threshold Worksheet	3-24
3-6 Sample EPCRA Section 313 Reporting Threshold Worksheet	3-25
4-1 Summary of Liquid Residue Quantities From Pilot-Scale Experimental Study (weight percent of drum capacity)	4-9
4-2 Potential Data Sources for Release and Other Waste Management Calculations	4-18
4-3 Release and Other Waste Management Quantity Estimation Worksheet	4-25

LIST OF FIGURES

	Page
2-1 EPCRA Section 313 Reporting Decision Diagram	2-3
4-1 Release and Other Waste Management Activity Calculation Approach	4-2
4-2 Possible Release and Other Waste Management Activity Types for EPCRA Section 313 Chemicals and Chemical Categories	4-5
4-3 Overall Process Flow Diagram - Semiconductor Manufacturing	4-33
4-4 Process Flow Diagram for Typical Photolithography Process	4-32
4-5 Process Flow Diagram for Typical Thin Film Process	4-38
4-6 Process Flow Diagram for Typical Etching Process	4-41
4-7 Process Flow Diagram for Typical Wafer Cleaning Process	4-44
4-8 Process Flow Diagram for Typical Doping Process	4-50
4-9 Process Flow Diagram for Typical Chemical Mechanical Planarization (CMP) Process	4-52

ACKNOWLEDGMENT

The U.S. EPA wishes to acknowledge the valuable contributions made by the staff and members of the Semiconductor Industry Association (SIA). Without the insight provided by those in the industry with actual experience in the fulfilling of the EPCRA Section 313 reporting requirements, we would not have been able to produce a document which we believe will be of great assistance to those who must prepare future EPCRA Section 313 reports. Special thanks go to Mr. Reed Content, Advanced Microdevices, Mr. Don Lassiter, SIA, and Ms. Karen Silberman, Motorola, for their hard work.

OVERVIEW

This document supersedes the booklet entitled *Title III Section 313 Release Reporting Guidance, Estimating Chemical Releases From Semiconductor Manufacturing*, dated January 1988. It is intended to assist establishments and facilities designated by Standard Industrial Classification (SIC) Code 3674 in complying with the Emergency Planning and Community Right-To-Know Act (EPCRA) Section 313 and Pollution Prevention Act (PPA) Section 6607 reporting requirements, the preparation of Form R or the alternate certification statement, Form A. The EPCRA Section 313 program is commonly referred to as the Toxic Chemical Release Inventory (TRI).

The principal differences in the new document include:

- More detailed examples;
- New EPCRA Section 313 regulations and guidance developed since 1988;
- PPA Section 6607 reporting requirements;
- U.S. Environmental Protection Agency's (EPA's) interpretive guidance on various issues specific to the Semiconductor Manufacturing industry; and
- EPCRA Section 313 issues regarding processes not discussed in the earlier document.

This document is designed to be a supplement to the annual issue of the *Toxic Chemical Release Inventory Reporting Forms and Instructions, (TRI Forms and Instructions)*. It is organized to provide a step-by-step guide to compliance with EPCRA Section 313 and PPA Section 6607, starting with how to determine if your facility must report and ending with guidance for estimating release and other waste management quantities.

Chapter 1 introduces EPCRA Section 313 and PPA Section 6607 reporting and provides a brief background on Section 313 of EPCRA and Section 6607 of PPA.

Chapter 2 discusses reporting requirements and begins with how to determine whether your facility must report. This determination is based on your answers to a series of four questions:

- Is your facility's primary Standard Industrial Classification (SIC) Code on the EPCRA Section 313 list?
- Does your facility employ ten or more full-time employees or the equivalent?
- Does your facility manufacture, process, or otherwise use any EPCRA Section 313 chemicals or chemical categories?
- Does your facility exceed any of the activity thresholds for an EPCRA Section 313 chemical or chemical category?

If the answer to **ANY ONE** of the first three questions is "No" you are not required to submit an EPCRA Section 313 report. If you answer "Yes" to **ALL** four questions, the next step is to determine what kind of report you must prepare, a Form R or the alternate certification statement, Form A. Chapter 2 provides detailed information on the requirements for each kind of report. Chapter 2 concludes with a discussion on how to address trade secrets and the records that should be kept to support your reporting.

Chapter 3 discusses how to calculate the activity thresholds (manufacture, process, and otherwise use) for the EPCRA Section 313 chemicals or chemical categories. Information is provided on how to determine which EPCRA Section 313 chemicals or chemical categories your facility manufactures, processes, or otherwise uses and how to calculate the quantities of each. Detailed information is also provided on the various exemptions:

- *De minimis* exemption;
- Article exemption;
- Facility-related exemption; and
- Activity-related exemptions.

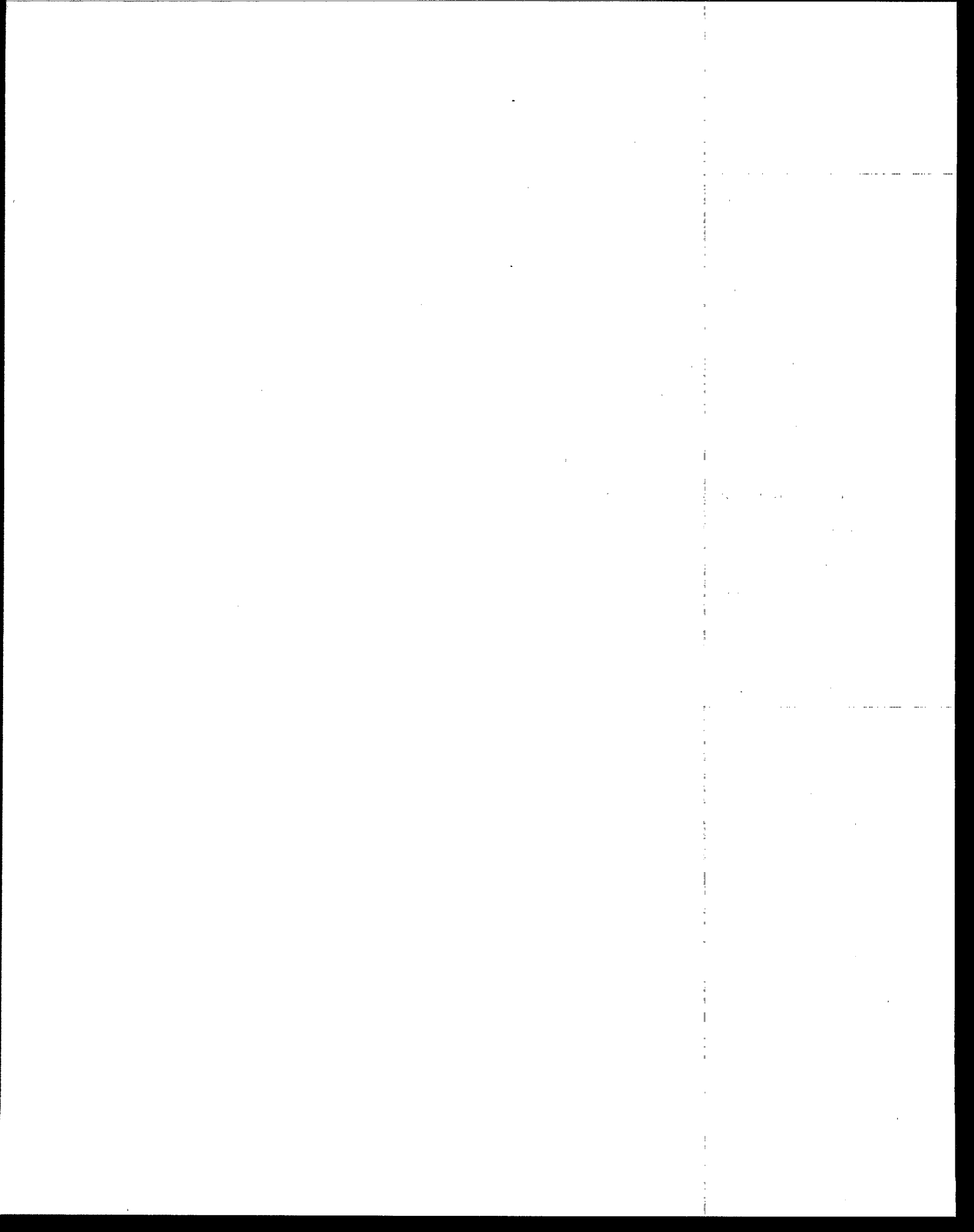
Chapter 3 concludes with a discussion of how to determine which EPCRA Section 313 chemicals or chemical categories exceed a reporting threshold.

Chapter 4 discusses how to estimate the release and other waste management amounts for those EPCRA Section 313 chemicals and chemical categories for which you must prepare a report. The first part of this chapter provides a step-by-step approach designed to minimize the risk of overlooking an activity involving an EPCRA Section 313 chemical or chemical category and any potential sources or types of release and other waste management activities. This procedure consists of:

- Preparation of a detailed **process flow diagram**;
- Identification of EPCRA Section 313 chemicals and chemical categories and potential **sources** of chemical release and other waste management activities;
- Identification of the potential **types** of release and other waste management activities from each source; and
- Determination of the most appropriate methods for **estimating the quantities** of EPCRA Section 313 chemical and chemical category release and other waste management activities.

The second part of Chapter 4 is organized around six common activities in the semiconductor manufacturing industry where EPCRA Section 313 chemicals and chemical categories are manufactured, processed, and otherwise used. The commonly used EPCRA Section 313 chemicals, process descriptions, reporting thresholds, release and other waste management estimates, and common problems are presented.

This document includes examples and common errors applicable to the semiconductor manufacturing industry. These are based on information received from representatives of the Semiconductor Industry Association, on the questions received by the EPCRA Hotline, and questions identified during voluntary site surveys of facilities that have filed EPCRA Section 313 reports in the past.



CHAPTER 1 - INTRODUCTION

1.0 PURPOSE

The purpose of this guidance manual is two-fold. The primary purpose is to assist Semiconductor Manufacturing facilities in complying with the reporting requirements of Section 313 of the Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA) and of Section 6607 of the Pollution Prevention Act of 1990 (PPA). This manual explains the EPCRA Section 313 reporting requirements and discusses specific release and other waste management activities encountered at facilities that produce semiconductor chips used in computers, cellular phones, pagers, calculators, and other electrical devices. Since each plant is unique, the recommendations presented may have to be modified for your particular facility. The secondary purpose is to provide information to other interested parties (such as management, legal professionals, inspectors, consultants, teachers, students, and to general public) about the processes and the toxic chemicals used in semiconductor manufacturing.

This manual is intended solely for guidance and does not alter any statutory or regulatory requirements. The document should be used in conjunction with the appropriate statutes and regulations but does not supersede them. Accordingly, the reader should consult other applicable documents (for example, the statute, the Code of Federal Regulations (CFR), relevant preamble language, and the current *Toxic Chemical Release Inventory Reporting Forms and Instructions (TRI Forms and Instructions)*).

This document supersedes the 1988 document entitled *Title III Section 313 Release Reporting Guidance, Estimating Chemical Releases from Semiconductor Manufacturing*. This new document includes:

- More detailed examples;
- New EPCRA Section 313 regulations and guidance developed since 1988;
- PPA Section 6607 reporting requirements;
- U.S. Environmental Protection Agency's (EPA's) interpretive guidance on various issues specific to the Semiconductor Manufacturing industry; and

- EPCRA Section 313 issues regarding processes not discussed in the earlier document.

It is intended to supplement the *TRI Forms and Instructions* document that is updated and published annually by U.S. EPA. It is essential that you use the current version of the *TRI Forms and Instructions* to determine if (and how) you should report. Changes or modifications to Toxic Chemical Release Inventory (TRI) reporting requirements are reflected in the annual *TRI Forms and Instructions* and should be reviewed before compiling information for the report.

The objectives of this manual are to:

- Reduce the level of effort expended by those facilities that prepare an EPCRA Section 313 report; and
- Increase the accuracy and completeness of the data being reported by the semiconductor manufacturing industry.

U.S. EPA cannot anticipate every potential issue or question that may apply to your facility. Therefore, this manual attempts to address those issues most prevalent or common for the semiconductor manufacturing industry. Used in conjunction with the most current *TRI Forms and Instructions* and *Estimating Releases and Waste Treatment Efficiencies for the Toxic Chemical Release Inventory Form (1999 version)*, facilities should be able to provide complete and accurate information for EPCRA Section 313 reporting. Additional discussions on specific issues can be found in U.S. EPA's current edition of *EPCRA Section 313, Questions and Answers* (the 1998 edition is EPA 745-B-98-004), which is available on the U.S. EPA's TRI website (<http://www.epa.gov/opptintr/tri>) or by contacting the **EPCRA Hotline at 1-800-424-9346**. In the Washington, DC metropolitan area, call 703-412-9810.

1.1 **Background on EPCRA Section 313 and PPA Section 6607**

The following overview of EPCRA Section 313 and Section 6607 of the PPA will provide you with a basic understanding of the objectives and requirements of this program, and will help you in completing your forms.

One of the primary goals of EPCRA is to increase the public's knowledge of, and access to, information on both the presence of toxic chemicals in their communities and on releases into the environment and other waste management activities of those chemicals. EPCRA Section 313 requires certain designated businesses (see SIC Code discussion, Chapter 2, Section 2.2) to submit annual reports (commonly referred to as Form R reports and Form A reports) on over 600 EPCRA Section 313 chemicals and chemical categories and the amounts released or otherwise managed as waste, even if there are no releases or other waste management quantities associated with these chemicals. Throughout this document, whenever EPCRA Section 313 chemicals are discussed, the discussion includes chemical categories, as appropriate. Chemicals or chemical categories may be added or deleted from the list. Therefore, before completing your annual report, be sure to check the most current list included with the *TRI Forms and Instructions* when evaluating the chemicals and chemical categories in use at your facility. Copies of the reporting package can be requested from the EPCRA Hotline, 1-800-424-9346.

All facilities meeting the EPCRA Section 313 reporting criteria must report the annual release and other waste management activity quantities (routine and accidental) of EPCRA Section 313 chemicals and chemical categories to all environmental media. A separate report is required for each EPCRA Section 313 chemical or chemical category that is manufactured (including imported), processed, or otherwise used above the reporting threshold. The reports must be submitted to U.S. EPA and State or Tribal governments, on or before July 1, for activities in the previous calendar year. The owner/operator of the facility on July 1 is primarily responsible for the report, even if the owner/operator did not own the facility during the reporting year. However, property owners with no business interest in the operation of the facility (for example, owners of an industrial park) are exempt from reporting requirements.

EPCRA also mandates U.S. EPA to establish and maintain a publicly available database system consisting of the information reported under Section 313 and under Section 6607 of the PPA. This database, known as the Toxic Chemical Release Inventory (TRI), can be accessed through the following sources:

- National Library of Medicine (NLM) TOXNET on-line system;

- U.S. EPA Internet site, <http://www.epa.gov/opptintr/tri>;
- Envirofacts Warehouse Internet site, <http://www.epa.gov/enviro/html/tris-query-java.html>;
- CD-ROM from the Government Printing Office;
- Microfiche in public libraries; and
- Magnetic tape and diskettes from the National Technical Information Service.

Information identified by the submitter as trade secret in accordance with the regulatory requirements is protected from public release. In addition to being a resource for the public, TRI data are also used in the research and development of regulations related to EPCRA Section 313 chemicals and chemical categories.

To reduce the reporting burden for small businesses, U.S. EPA established an alternate activity threshold of one million pounds manufactured, processed, or otherwise used for facilities with total annual reportable amounts of 500 pounds or less of the EPCRA Section 313 chemical or chemical category. Provided the facility does not exceed either the reportable amount or the alternate threshold, the facility may file a certification form (Form A) rather than a Form R. By filing the Form A, the facility certifies that they do not exceed the reportable amount of 500 pounds or exceed the alternate threshold of one million pounds.

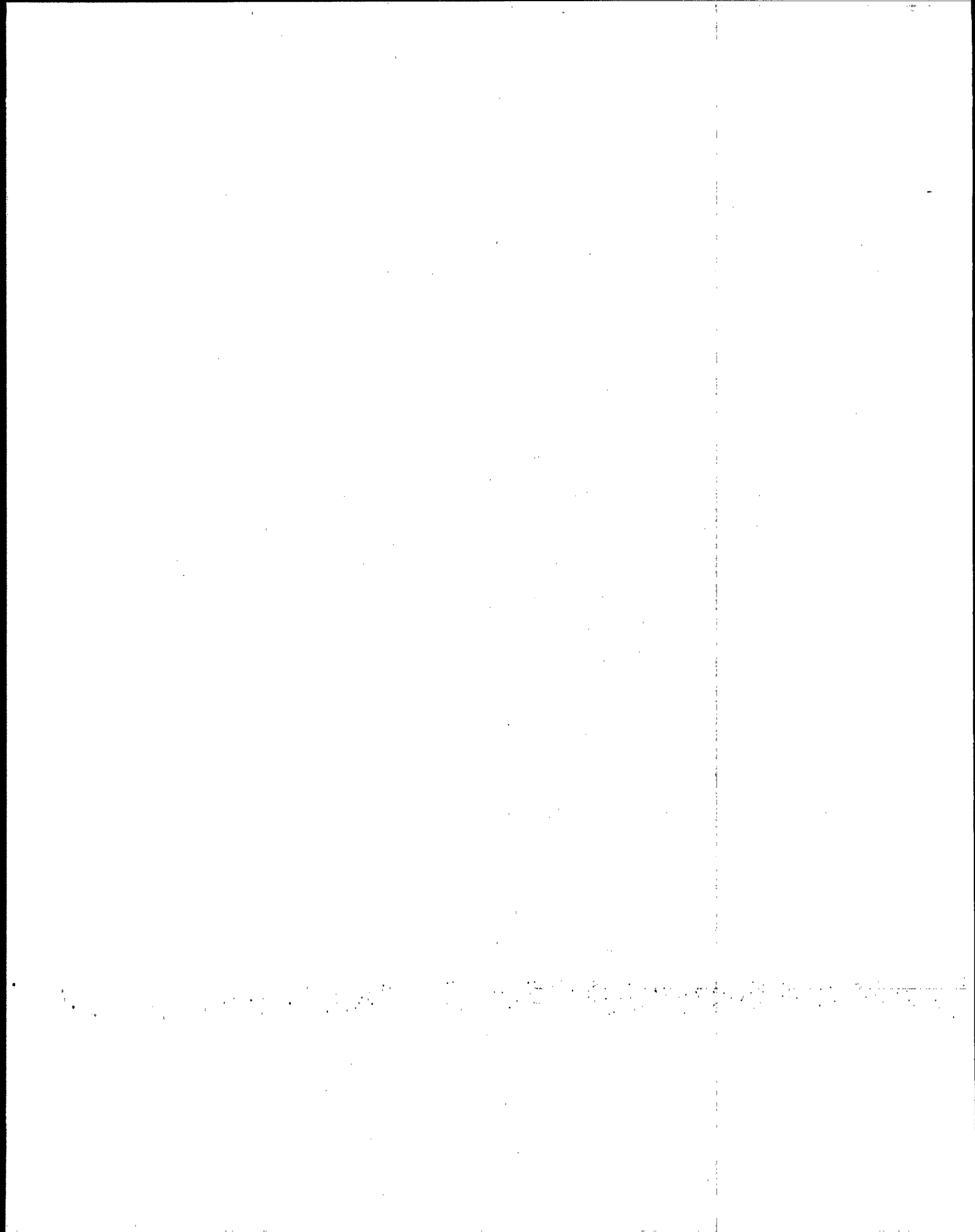
Note that the annual reportable amount includes the quantity of the EPCRA Section 313 chemical or chemical category in all production-related waste management activities, not just releases (see the discussion in Section 2.8 for more detail). Also note that either a Form A or a Form R, but not both, must be submitted for each EPCRA Section 313 chemical or chemical category above any reporting threshold, even if there are zero release and other waste management activity quantities.

Violation of EPCRA Section 313 reporting provisions may result in federal civil penalties of up to \$27,500 per day for each violation (61 FR 69360). State enforcement provisions may also be applicable depending on the state's EPCRA Section 313 reporting regulations.

Members of the Semiconductor Industry Association provided input on common problems specific to the semiconductor manufacturing industry that are encountered by those completing EPCRA Section 313 reports. U.S. EPA has combined this input with questions forwarded to the EPCRA Hotline and those identified during voluntary site surveys of facilities that have filed EPCRA Section 313 reports in the past. Selected issues and guidance addressing these common problems are presented throughout this document as applicable.

The *TRI Forms and Instructions* and *The 1994 and 1995 Toxic Release Inventory Data Quality Report*, EPA 745-R-98-002, also contains discussions of common problems in completing the EPCRA Section 313 reports. You are encouraged to read both documents before filling out the Form R (or Form A) for your facility.

If, after reading this manual, you still have questions about EPCRA Section 313 reporting, please contact the EPCRA Hotline at 1-800-424-9346. Assistance is also available from the designated EPCRA Section 313 Coordinator in the U.S. EPA regional office and the EPCRA contact in your state (see the *TRI Forms and Instructions* for a current list of these contacts). Additional guidance is also available in the resources listed in Appendix A.



CHAPTER 2 - REPORTING REQUIREMENTS

2.0

PURPOSE

The purpose of this chapter is to help you determine if you must prepare an EPCRA Section 313 report(s) and, if so, what kind of a report(s) should be prepared (Form R or the alternate certification statement, the Form A). This chapter presents the EPCRA Section 313 reporting requirements to help you determine if these requirements apply to your facility. It also discusses the reporting of trade secrets and the records that must be kept.

To understand the following discussion you must first understand how EPCRA defines a facility. The term "facility" is defined as, "all buildings, equipment, structures, and other stationary items which are located on a single site or on contiguous or adjacent sites and which are owned or operated by the same person (or by any person which controls, is controlled by, or is under common control with such person). A facility may contain more than one "establishment" (40 CFR 372.3). An "establishment" is defined as, "an economic unit, generally at a single physical location, where business is conducted, or services or industrial operations are performed" (40 CFR 372.3).

U.S. EPA recognizes that for business reasons it may be easier and more appropriate for multiple establishments at one facility to report separately. However, the combined quantities of EPCRA Section 313 chemicals and chemical categories manufactured, processed, or otherwise used in all establishments in that facility must be considered for threshold determinations. Also, the combined release and other waste management activity quantities reported singly for each establishment must equal those for the facility as a whole.

Note that if a facility is comprised of more than one establishment, once an activity threshold is met by the facility, providing the facility meets SIC Code and employee criteria, release and other waste management activities from all establishments at the facility must be reported.

Example - Multiple Establishments

Your facility has several different establishments, all with SIC Codes covered by EPCRA Section 313. One establishment used 7,000 pounds of toluene, an EPCRA Section 313 chemical, during the year to clean equipment. Another establishment purchased and used 4,000 pounds of toluene during the year as a semiconductor manufacturing aid. Both activities constitute otherwise use of the EPCRA Section 313 chemical (as presented in Section 2.5 and described in detail in Chapter 3) and the total for the facility exceeded the 10,000-pound otherwise use threshold for the year. Thus, if your facility meets the employee threshold, you must file either one Form R for that chemical from your facility, or two Form Rs, one from each establishment. Please note that you may be eligible to file one Form A for the facility but you cannot file a separate Form A for each establishment.

2.1 Must You Report?

How do you determine if your facility must prepare an EPCRA Section 313 report? Your answers to the following four questions will help you decide (illustrated by Figure 2-1):

- 1) Is the primary SIC Code for your facility included in the list covered by EPCRA Section 313 reporting (see Section 2.2)?
- 2) Does your facility have 10 or more full-time employees or the equivalent (see Section 2.3)?
- 3) Does your facility manufacture (which includes importation), process, or otherwise use EPCRA Section 313 chemicals or chemical categories (see Section 2.4)?
- 4) Does your facility exceed any applicable thresholds of EPCRA Section 313 chemicals or chemical categories (25,000 pounds per year for manufacturing; 25,000 pounds per year for processing; or 10,000 pounds per year for otherwise use -- see Section 2.5)?

If you answered "No" to any of the first three questions, you are not required to prepare any EPCRA Section 313 reports. If you answered "Yes" to ALL of the first three questions, you must complete a threshold calculation for each EPCRA Section 313 chemical at the facility, and submit an EPCRA Section 313 report for each chemical and chemical category exceeding the applicable threshold.

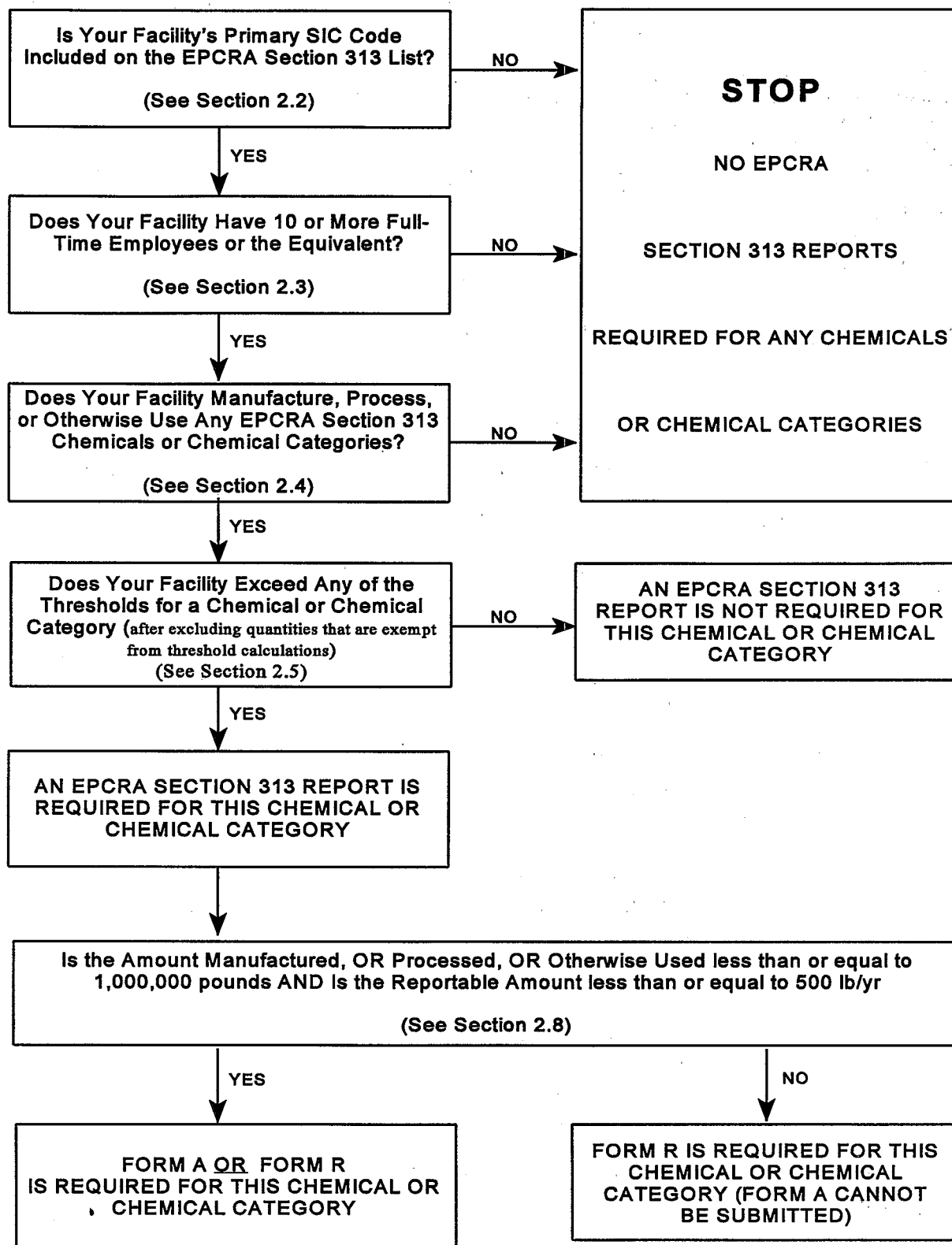


Figure 2-1. EPCRA Section 313 Reporting Decision Diagram

2.2

SIC Code Determination

Facilities with the SIC Codes presented in Table 2-1 are covered by the EPCRA Section 313 reporting requirements.

Table 2-1**SIC Codes Covered by EPCRA Section 313 Reporting**

SIC Code Major Groups		
SIC Codes	Industry	Qualifiers
10	Metal Mining	Except SIC Codes 1011, 1081, and 1094
12	Coal Mining	Except SIC Code 1241
20 through 39	Manufacturing	None
4911, 4931, and 4939	Electric and Other Services and Combination Utilities	Limited to facilities that combust coal and/or oil for the purpose of generating electricity for distribution in commerce
4953	Refuse Systems	Limited to facilities regulated under RCRA Subtitle C
5169	Chemicals and Allied Products	None
5171	Petroleum Bulk Stations and Terminals	None
7389	Business Services	Limited to facilities primarily engaged in solvent recovery services on a contract or fee basis

Most semiconductor manufacturing industry facilities fall under SIC Code 3674 (Semiconductors and Related Devices) and are required to prepare a report (or reports) if they meet the employee and chemical activity thresholds. However, you should determine the SIC Code(s) for your facility based on the activities on site. For assistance in determining which SIC Code best suits your facility refer to *Standard Industrial Classification Manual, 1987* published by the Office of Management and Budget.

Note that auxiliary facilities can assume the SIC Code of another covered establishment if the primary function is to support the covered establishment's operations. For the purpose of EPCRA Section 313, auxiliary facilities are defined as those that are primarily

engaged in performing support services for another covered establishment or multiple establishments of a covered facility, and are in a different physical location from the primary facility. In addition, auxiliary facilities perform an integral role in the primary facility's activities. In general, the auxiliary facility's basic administrative services (e.g., paperwork, payroll, employment) are performed by the primary facility. If an auxiliary facility's primary function is to support/service a facility with a covered SIC Code, the auxiliary facility assumes the covered SIC Code as its primary SIC Code and therefore is covered by the EPCRA Section 313 reporting requirements. However, if the SIC Code for the primary facility is not covered by EPCRA Section 313, then neither the primary nor the auxiliary facility is required to submit a report.

If your facility has more than one SIC Code (i.e., several establishments with different SIC Codes are owned or operated by the same entity and are located at your facility), you are subject to reporting requirements if:

- All the establishments have SIC Codes covered by EPCRA Section 313;
OR
- The total value of the products shipped or services provided at establishments with covered SIC Codes is greater than 50% of the value of the entire facility's products and services; OR
- Any one of the establishments with a covered SIC Code ships and/or produces products or provides services whose value exceeds the value of services provided, products produced, and/or shipped by any other establishment within the facility.

A pilot plant within a covered SIC Code is considered a covered facility and is subject to reporting, provided it meets the employee and activity criteria (note that pilot plants are not eligible for the laboratory exemption, which is discussed in Chapter 3). Warehouses on the same site as facilities in a covered SIC Code are also subject to reporting. Likewise, warehouses that qualify as auxiliary facilities of covered facilities also must report, provided all applicable thresholds are met.

While you are currently required to determine your facility's reporting eligibility based on the SIC code system described above, it is important to be aware that the SIC code system will be replaced by a new system in the future. On April 9, 1997 (62 FR 17287), the

Office of Management and Budget promulgated the North American Industrial Classification System (NAICS). NAICS is a new economic classification system that replaces the SIC code system as a means of classifying economic activities for economic forecasting and statistical purposes. The transition to the new NAICS may require statutory and/or regulatory actions. As a result, the SIC code system is still required to be used as the mechanism to determine your facility's reporting eligibility. EPA will issue notice in the *Federal Register* to inform you and other EPCRA Section 313 facilities of its plans to adopt the NAICS and how facilities should make their NAICS code determination.

2.3 **Number of Employees**

If your facility meets SIC Code and activity threshold criteria, you are required to prepare an EPCRA Section 313 report if your facility has 10 or more full-time employees or the equivalent. A full-time employee equivalent is defined as a work year of 2,000 hours. If your facility's employees aggregate 20,000 or more hours in a calendar year, you meet the 10 or more employee criterion.

The following should be included in your employee calculations:

- Owners;
- Operations/manufacturing staff;
- Clerical staff;
- Temporary employees;
- Sales personnel;
- Truck drivers (employed by the facility);
- Other non-manufacturing or off-site facility employees directly supporting the facility;
- Paid vacation and sick leave; and
- Contractor employees (maintenance, construction, etc. but excluding contracted truck drivers).

In general, if an individual is employed or hired to work at the facility, all the hours worked by that individual must be counted in determining if the 20,000-hour criterion has been met.

Example - Employee Equivalent Calculation

Your facility has six full-time employees working 2,000 hours/year. You also employ two full-time sales people and a delivery truck driver (employed by the facility) who are assigned to the plant, each working 2,000 hours/year but predominantly on the road or from their homes. The wastewater treatment plant (on site and owned by the facility) is operated by a contractor who spends an average of two hours per day and five days per week at the plant. Finally, you built an addition to the plant warehouse during the year, using four contractor personnel who were on site full time for six months (working on average of 1,000 hours each). You would calculate the number of full-time employee equivalents as follows:

- Hours for your nine full-time employees (six plant personnel, two salespeople, and one delivery truck driver) are:
 $(9 \text{ employees}) \times (2,000 \text{ hours/year}) = 18,000 \text{ hours/year}$
- Hours for the wastewater treatment plant operator are:
 $(2 \text{ hours/day}) \times (5 \text{ days/week}) \times (52 \text{ weeks/year}) = 520 \text{ hours/year; and}$
- Hours for the construction crew are:
 $(4 \text{ contractors}) \times (1,000 \text{ hours}) = 4,000 \text{ hours/year.}$

Your facility has a total of 22,520 hours for the year, which is above the 20,000 hours/year threshold; therefore, you meet the employee criterion.

2.4

Manufacturing, Processing, and Otherwise Use of EPCRA Section 313 Chemicals or Chemical Categories

If you are in a covered SIC Code and have 10 or more full-time employee equivalents, you must determine which EPCRA Section 313 chemicals and chemical categories are manufactured, processed, or otherwise used at your facility. You should prepare a list that includes all chemicals and chemical categories found in mixtures and trade name products at all establishments at the facility. This list should then be compared to the CURRENT list of EPCRA Section 313 chemicals and chemical categories found in the *TRI Forms and Instructions* document for that reporting year (also available from the EPCRA Hotline, 1-800-424-9346). Once you identify the EPCRA Section 313 chemicals and chemical categories at your facility, you must evaluate the activities involving each chemical and chemical category and determine if any activity thresholds are met.

Note that chemicals and chemical categories are periodically added, delisted, or modified. Therefore, it is imperative that you refer to the appropriate reporting year's list. Also, note that a list of synonyms for EPCRA Section 313 chemicals and chemical categories can be

found in the U.S. EPA publication *Common Synonyms for Chemicals Listed Under Section 313 of the Emergency Planning and Community Right-To-Know Act* (EPA 745-R-95-008). Table 2-2 lists the EPCRA Section 313 chemicals and chemical categories most frequently reported for the semiconductor manufacturing industry and the process in which they are typically used. This list is not intended to be all inclusive and should only be used as a guide.

Table 2-2

EPCRA Section 313 Chemicals and Chemical Categories Commonly Encountered in Semiconductor Manufacturing

Unit Operation	Typical EPCRA Section 313 Chemicals
Photolithography	Xylenes, ammonia, N-methyl-2-pyrrolidone, glycol ethers, methyl ethyl ketone, ethylbenzene, dichloroethylene
Thin Films	Ammonia (silicon nitride film deposition), copper
Cleaning/Etching	Ethylene glycol, glycol ethers, methanol, N-methyl-2-pyrrolidone, sulfuric acid aerosols (spray etching/cleaning), hydrochloric acid aerosols (spray etching/cleaning), hydrogen fluoride, nitric acid, nitrate compounds, ammonia
Doping	Arsenic, antimony, phosphine
Chemical Mechanical Planarization	Nitrate compounds, copper

2.5 Activity Categories

EPCRA Section 313 defines three activity categories for the listed chemicals and chemical categories: manufacturing (which includes importing), processing, and otherwise use. The activity thresholds are 25,000 pounds per year for manufacturing, 25,000 pounds per year for processing, and 10,000 pounds per year for otherwise use. These thresholds apply to each chemical and chemical category individually. The quantity of chemicals or chemical categories stored on site or purchased is not relevant for threshold determinations. Rather, the determination is based solely on the quantity actually manufactured (including imported), processed, or otherwise used. Therefore, EPCRA Section 313 chemicals and chemical categories that are brought on site and stored, but are not incorporated into a product for distribution or not otherwise used on site during the reporting year, are not considered towards any activity thresholds.

Expanded definitions with examples of each of the three activities are found in Chapter 3, Tables 3-2, 3-3, and 3-4. The terms are briefly defined as follows:

Table 2-3
Activity Categories

Activity Category	Definition	Threshold (lb/yr)
Manufacture	To produce, prepare, import, or compound an EPCRA Section 313 chemical or chemical category. Manufacture also applies to an EPCRA Section 313 chemical or chemical category that is produced coincidentally during the manufacture, processing, otherwise use, or disposal of another chemical or mixture of chemicals as a byproduct, and an EPCRA Section 313 chemical or chemical category that remains in that other chemical or mixture of chemicals as an impurity during the manufacturing, processing, or otherwise use or disposal of any other chemical substance or mixture. An example would be the production of ammonia or nitrate compounds in a wastewater treatment system.	25,000
Process	To prepare a listed EPCRA Section 313 chemical or chemical category, or a mixture or trade name product containing an EPCRA Section 313 chemical or chemical category, for distribution in commerce (usually the intentional incorporation of an EPCRA Section 313 chemical or chemical category into a product). For example, arsenic may be used as a dopant, and would have to be reported if you exceeded the reporting threshold. Processing includes the preparation for sale to your customers (and transferring between facilities within your company) of a chemical or formulation that you manufacture. For example, if you manufacture a chemical or product, package it, and then distribute it into commerce, this chemical has been manufactured AND processed by your facility.	25,000
Otherwise Use	<p>Generally, use of an EPCRA Section 313 chemical or chemical category that does not fall under the manufacture or process definitions is classified as otherwise use. An EPCRA Section 313 chemical or chemical category that is otherwise used is not intentionally incorporated into a product that is distributed in commerce, but may be used instead as a manufacturing or processing aid (e.g., catalyst), in waste processing, or as a fuel (including waste fuel). For example, acids used to clean equipment are classified as otherwise used.</p> <p>On May 1, 1997 U.S. EPA revised the interpretation of otherwise use. The following new otherwise use definition becomes effective with the 1998 reporting year (62 FR 23834, May 1, 1997):</p> <p>Otherwise use means "any use of a toxic chemical contained in a mixture or other trade name product or waste, that is not covered by the terms manufacture or process. Otherwise use of a toxic chemical does not include disposal, stabilization (without subsequent distribution in commerce), or treatment for destruction unless:</p> <ol style="list-style-type: none"> 1) The toxic chemical that was disposed, stabilized, or treated for destruction was received from off site for the purposes of further waste management; OR 2) The toxic chemical that was disposed, stabilized, or treated for destruction was manufactured as a result of waste management activities on materials received from off site for the purposes of further waste management activities." 	10,000

COMMON ERROR - Coincidental Manufacture

The coincidental manufacture of an EPCRA Section 313 chemical, outside the primary product process line but in direct support of the process, is frequently overlooked. For example, semiconductor manufacturers often use halogenated organic gases in plasma environments for various cleaning and etching operations. EPCRA Section 313 chemicals may be coincidentally manufactured by the degradation of these compounds. The amount of each coincidentally manufactured chemical must be included in the manufacturing threshold determination and, if a threshold is exceeded, any subsequent release and other waste management activity calculations. Typical EPCRA Section 313 chemicals coincidentally manufactured from these activities include hydrofluoric acid and aerosol forms of hydrochloric acid.

Relabeling or redistribution of an EPCRA Section 313 chemical where no repackaging occurs does not constitute manufacturing, processing, or otherwise use of that chemical. This type of activity should not be included in threshold calculations.

Also, note that the threshold determinations for the three activity categories (manufacturing, processing, and otherwise use) are mutually exclusive. That is, you must conduct a separate threshold determination for each activity category and if you exceed any threshold, all release and other waste management activities of that EPCRA Section 313 toxic chemical or chemical category at the facility must be considered for reporting.

Example - Relabeling

You buy a mixture in small containers which contains an EPCRA Section 313 chemical or chemical category. When it arrives you put your own label on each container and put the containers in a larger box with several other items you manufacture, and sell the larger box as a kit. The quantity of the EPCRA Section 313 chemical or chemical category in the small containers should not be counted toward the processing (because you did not repackage the toxic chemical) or otherwise use thresholds, nor should it be counted toward the manufacturing activity threshold unless the small containers were imported. However, you must consider other EPCRA Section 313 chemicals and chemical categories that you manufactured in the kit toward manufacturing and processing threshold determinations.

2.6 How Do You Report?

You must submit an EPCRA Section 313 report for each EPCRA Section 313 chemical or chemical category that exceeds a threshold for manufacturing, OR processing, OR otherwise use (providing you meet the employee and SIC Code criteria). Provided you do not exceed certain alternate activity thresholds and total annual reportable amounts, you may prepare a Form A (See Section 2.8) rather than a Form R. The *TRI Forms and Instructions* contain detailed directions for the preparation and submittal of EPCRA Section 313 reports for each listed chemical for the reporting year. The *TRI Forms and Instructions* are sent to all facilities

that submitted EPCRA Section 313 reports the preceding year. However, if you do not receive a courtesy copy, you may request copies of the *TRI Forms and Instructions* from the EPCRA Hotline (1-800-424-9346).

2.7 Form R

Form R is the more detailed and more common EPCRA Section 313 report. If you are submitting a Form R, it is essential that you use the *TRI Forms and Instructions* for the appropriate reporting year. U.S. EPA encourages the electronic submittal of the Form R, via the Automated Toxic Chemical Release Inventory Reporting Software (ATRS). Use of the ATRS will save preparation time in data entry and photocopying and reduce errors via on-line validation routines and use of pick lists. The ATRS can be found on the Internet at:

- **<http://www.epa.gov/opptintr/atrs>**

The ATRS is available in both DOS and Windows versions. More information can be found in the *TRI Forms and Instructions* and by calling the ATRS User Support Hotline at (703) 816-4434.

The Form R consists of two parts:

Part I, Facility Identification Information. This part may be photocopied and reused for each Form R you submit, except for the signature which must be original for each submission.

Part II, Chemical Specific Information. You must complete this part separately for each EPCRA Section 313 chemical or chemical category; it cannot be reused year to year even if reporting has not changed.

Submission of incomplete EPCRA Section 313 reports may result in issuance of a Notice of Technical Error (NOTE), Notice of Significant Error (NOSE), or Notice of Noncompliance (NON). See the current *TRI Forms and Instructions* for more detailed information on completing the Form R and submitting the EPCRA Section 313 report.

2.8

Alternate Threshold and Form A

U.S. EPA developed the Form A, also referred to as the "Certification Statement," to reduce the annual reporting burden for facilities with minimal amounts of EPCRA Section 313 chemicals or chemical categories released and otherwise managed as a waste (59 FR 61488, November 1994; applicable beginning reporting year 1994 and beyond). A facility must meet the following two criteria in order to submit a Form A:

- First, the total annual reportable amount of the EPCRA Section 313 chemical or chemical category cannot exceed 500 pounds per year. The "reportable amount" is defined as the sum of the on-site amounts released (including disposal), treated, recycled, and combusted for energy recovery, combined with the sum of the amounts transferred off site for recycling, energy recovery, treatment, and/or release (including disposal). This total corresponds to the total of data elements 8.1 through 8.7 on the 1997 version of the Form R.
- Second, the amount of the chemical manufactured, processed, OR otherwise used cannot exceed one million pounds. It is important to note that the quantities for each activity are mutually exclusive and must be evaluated independently. If the quantity for any one of the activities exceeds 1,000,000 pounds a Form A cannot be used.

Example - Form A Threshold

Providing the combined annual reportable amounts from all activities does not exceed 500 pounds, a facility that manufactures 900,000 pounds of an EPCRA Section 313 chemical or chemical category and processes 150,000 pounds of the same listed toxic chemical or chemical category is eligible to use the Form A because the facility did not exceed the one million pound threshold for either activity, even though the total activity usage exceeds one million pounds.

The Form A Certification Statement must be submitted for each eligible EPCRA Section 313 chemical or chemical category. The information on the Form A will be included in the publicly accessible TRI database; however, these data are marked to indicate that they represent certification statements rather than Form Rs. Note that separate establishments at a facility cannot submit separate Form As for the same chemical or chemical category; rather, only one Form A per EPCRA Section 313 chemical or chemical category can be submitted per facility.

Like the Form R, Form A requests facility identification information. However, no release and other waste management estimations to any media are required. You must simply certify that the total annual reportable amount did not exceed 500 pounds and that amounts manufactured, processed, or otherwise used did not exceed one million pounds. Once the facility has completed estimates to justify the submission of a Form A, there is a considerable time savings in using the Form A, especially in subsequent years, providing activities involving the chemical or chemical category did not change significantly. It is strongly recommended that you document your initial rationale and refer to it every year to verify that you have not modified a part of the process that would invalidate the initial rationale supporting submission of Form A.

2.9 Trade Secrets

If you submit trade secret information, you must prepare two versions of the substantiation form as prescribed in 40 CFR Part 350 (see 53 FR 28801, July 29, 1988) as well as two versions of the EPCRA Section 313 report. One set of reports should be "sanitized" (i.e., it should provide a generic name for the EPCRA Section 313 chemical or chemical category identity). This version will be made available to the public. The second version, the "unsanitized" version, should provide the actual identity of the EPCRA Section 313 chemical or chemical category and have the trade secret claim clearly marked in Part I, Section 2.1 of the Form R or Form A. The trade secrets provision only applies to the EPCRA Section 313 chemical or chemical category identity. All other parts of the Form R or Form A must be filled out accordingly.

Individual states may have additional criteria for confidential business information and the submittal of both sanitized and unsanitized reports for EPCRA Section 313 chemicals and chemical categories. Facilities may jeopardize the trade secret status of an EPCRA Section 313 chemical or chemical category by submitting an unsanitized version to a state agency or tribal government that does not require an unsanitized version.

More information on trade secret claims, including contacts for individual state's submission requirements, can be found in the *TRI Forms and Instructions*.

Recordkeeping

Complete and accurate records are absolutely essential to meaningful compliance with EPCRA Section 313 reporting requirements. Compiling and maintaining good records will help you to reduce the effort and cost in preparing future reports, and to document how you arrived at the reported data in the event of U.S. EPA compliance audits. U.S. EPA requires you to maintain records substantiating each EPCRA Section 313 report submission for a minimum of three years. Each facility must keep copies of every EPCRA Section 313 report along with all supporting documents, calculations, work sheets, and other forms that you used to prepare the EPCRA Section 313 report. U.S. EPA may request this supporting documentation during a regulatory audit.

Specifically, U.S. EPA requires the following records be maintained for a period of three years from the date of the submission of a report (summarized from 40 CFR 372.10):

- 1) A copy of each EPCRA Section 313 report that is submitted.
- 2) All supporting materials and documentation used to make the compliance determination that the facility or establishment is a covered facility.
- 3) Documentation supporting the report submitted, including:
 - Claimed allowable exemptions,
 - Threshold determinations,
 - Calculations for each quantity reported as being released, either on or off site, or otherwise managed as waste,
 - Activity determinations, including dates of manufacturing, processing, or use,
 - The basis of all estimates,
 - Receipts or manifests associated with transfers of each EPCRA Section 313 chemical or chemical category in waste to off-site locations, and
 - Waste treatment methods, treatment efficiencies, ranges of influent concentrations to treatment, sequential nature of treatment steps, and operating data to support efficiency claims.
- 4) For facilities submitting a Form A, all supporting materials used to make the compliance determination that the facility or establishment is eligible to submit a Form A, including:

- Data supporting the determination the alternate threshold applies,
- Calculations of the annual reportable amounts,
- Receipts or manifests associated with the transfer of each EPCRA Section 313 chemical or chemical category in waste to off-site locations, and
- Waste treatment methods, treatment efficiencies, ranges of influent concentrations to treatment, sequential nature of treatment steps, and operating data to support efficiency claims.

Because EPCRA Section 313 reporting does not require additional testing or monitoring you must determine the best readily available source of information for all estimates. Some facilities may have detailed monitoring data and off-site transfer records that can be used for estimates while others may only have purchase and inventory records. Examples of records that you should keep, if applicable, might include:

- Each EPCRA Section 313 report submitted;
- EPCRA Section 313 Reporting Threshold Worksheets (sample worksheets can be found in Chapter 3 of this document as well as in the *TRI Forms and Instructions*);
- EPCRA Section 313 Reporting Release and Other Waste Management Quantity Estimation Worksheets (sample worksheets can be found in Chapter 4 of this document);
- Engineering calculations and other notes;
- Purchase records from suppliers;
- Inventory data;
- New Source Performance Standards;
- National Pollutant Discharge Elimination System (NPDES)/State Pollutant Discharge Elimination System (SPDES) permits and monitoring reports;
- EPCRA Section 312, Tier II reports;
- Monitoring records;
- Air permits;
- Flow measurement data;
- Resource Conservation Recovery Act (RCRA) hazardous waste generator's reports;
- Pretreatment reports filed with local governments;
- Invoices from waste management firms;
- Manufacturer's estimates of treatment efficiencies;
- Comprehensive Environmental Response, Conservation, and Liability Act of 1980 (CERCLA) Reportable Quantity (RQ) reports;
- RCRA manifests; and
- Process flow diagrams (including emissions, releases, and other waste management activities).

CHAPTER 3 - EPCRA SECTION 313 CHEMICAL OR CHEMICAL CATEGORY ACTIVITY THRESHOLD DETERMINATIONS

3.0 PURPOSE

This chapter provides a step-by-step procedure for determining if any EPCRA Section 313 chemicals or chemical categories exceed a reporting threshold. Threshold determinations are essentially a three step process:

- Step 1)* Identify any EPCRA Section 313 chemicals and chemical categories you manufacture/import, process, or otherwise use.
- Step 2)* Identify the activity category and any exempt activities for each EPCRA Section 313 chemical or chemical category.
- Step 3)* Calculate the quantity of each EPCRA Section 313 chemical or chemical category and determine which ones exceed an activity threshold.

3.1 Step 1 - Identify Which EPCRA Section 313 Chemicals or Chemical Categories are Manufactured (Including Imported), Processed, or Otherwise Used

Compile lists of all chemicals and mixtures at your facility. For facilities with many different chemicals and mixtures it is often helpful to prepare two lists: one with the pure (single ingredient) chemicals (including chemical compounds) and one with the mixtures and trade name products. On the second list, under the name of each mixture/trade name product, write the names of all chemicals in that product. Next, compare the chemicals and chemical categories on both lists to the current EPCRA Section 313 chemicals and chemical categories list found in the *TRI Forms and Instructions* (remember that chemicals and chemical categories may be periodically added and deleted and you should use the current reporting year's instructions). Highlight the EPCRA Section 313 chemicals and chemical categories that are on your list.

Review the list to be sure each chemical and chemical category is shown by its correct EPCRA Section 313 name. For example, a common EPCRA Section 313 chemical

found in the semiconductor manufacturing industry is methyl ethyl ketone. Methyl ethyl ketone (Chemical Abstracts Service (CAS) Registry No. 78-93-3) has several synonyms including MEK and 2-butanone. It must be reported on Form R (or Form A), Item 1.2, by its EPCRA Section 313 chemical name, methyl ethyl ketone. Synonyms can be found in the U.S. EPA document *Common Synonyms for Chemicals Listed Under Section 313 of the Emergency Planning and Community Right-to-Know Act* (EPA 745-R-95-008).

The original list of chemicals and chemical categories subject to EPCRA Section 313 reporting was a combination of chemical lists from New Jersey and Maryland. Refinements to the list have been made and changes are anticipated to continue. The list can be modified by U.S. EPA initiative or industry or the public can petition U.S. EPA to modify the list. When evaluating a chemical or chemical category for addition or deletion from the list, U.S. EPA must consider the chemical's potential acute human health effects and chronic human health effects or its adverse environmental effects. U.S. EPA reviews these petitions and initiates a rulemaking to add or delete the chemical or chemical category from the list, or publishes an explanation why it denied the petition.

While you must consider every chemical on the EPCRA Section 313 chemical and chemical category list, you should be aware of the chemicals and chemical categories typically used in the semiconductor manufacturing industry. As a guide, the most frequently reported EPCRA Section 313 chemicals and chemical categories for reporting year 1995 by semiconductor manufacturers (SIC Code 3674), and the processes they are typically used in are listed in Table 2-2.

A computerized spreadsheet may be helpful in developing your facility's chemical and chemical category list and performing threshold calculations. The spreadsheet could show the chemical, chemical category, or chemical mixture with corresponding component concentrations; the yearly quantity manufactured, processed, or otherwise used; and the CAS Registry number. The spreadsheet could also be designed to identify the total quantity by activity category (amounts manufactured, processed, and otherwise used) for each EPCRA Section 313 chemical or chemical category in every mixture, compound, and trade name product.

An initial investment of time will be required to develop this spreadsheet; however, the time and effort saved in threshold calculations in subsequent years will be significant. Such a system will also reduce the potential of inadvertently overlooking EPCRA Section 313 chemicals or chemical categories present in mixtures purchased from off-site sources.

To develop the chemical and chemical category list and the associated activity categories you may want to consult the following:

- Material Safety Data Sheets (MSDSs);
- Facility purchasing records;
- New Source Performance Standards;
- Inventory records;
- Air and water discharge permits;
- Individual manufacturing/operating functions; and
- Receipts or manifests associated with the transfer of each EPCRA Section 313 chemical and chemical category in waste to off-site locations.

The following is suggested useful information needed to prepare your EPCRA Section 313 reports and should be included for each chemical and chemical category on your spreadsheet:

- The mixture name and associated EPCRA Section 313 chemical and chemical category names;
- The associated CAS Registry numbers;
- The trade name for mixtures and compounds;
- The throughput quantities; and
- Whether the chemical or chemical category is manufactured, processed, or otherwise used at the facility (be sure to include quantities that are coincidentally manufactured and imported, as appropriate).

MSDSs are one of the best sources of information for the type and composition of chemicals and chemical categories in mixtures, and for determining whether you have purchased raw materials that contain EPCRA Section 313 chemicals and chemical categories. As of 1989, chemical suppliers to facilities in SIC Major Group Codes 20 through 39 are required to notify customers of any EPCRA Section 313 chemicals and chemical categories present in mixtures or trade name products distributed to facilities. The notice must be provided to the receiving

facility and may be attached or incorporated into that product's MSDS. If no MSDS is required, the notification must be in a letter that accompanies the first shipment of the product to your facility each year. This letter must contain the chemical name, CAS Registry number, and the weight or volume percent (or range) of the EPCRA Section 313 chemical or chemical category in mixtures or trade name products.

Carefully review the entire MSDS. Although new MSDSs must list whether EPCRA Section 313 chemicals and chemical categories are present, the language and location of this notification is not currently standardized. Depending on the supplier, this information could be found in different sections of the MSDS. The most likely sections of an MSDS to provide information on EPCRA Section 313 chemicals and chemical categories are:

- Physical properties/chemical composition section;
- Regulatory section;
- Hazardous components section;
- Labeling section; and
- Additional information section.

Also, many EPCRA Section 313 chemicals or chemical categories are present as impurities in mixtures. These quantities must also be considered in threshold determinations unless the concentration is below the *de minimis* value (see Section 3.2.2.1). In some cases, if the EPCRA Section 313 chemical or chemical category is present below *de minimis* concentration, it may be exempt.

Qualifiers

Several chemicals on the EPCRA Section 313 chemical list include qualifiers related to use or form. Some chemicals are reportable ONLY if manufactured by a specified process or in a specified activity category. For example, isopropyl alcohol is only reportable if it is manufactured using the strong acid process and saccharin is reportable only if it is manufactured. Some other chemicals are only reportable if present in certain forms. For example, only yellow or white phosphorus is reportable, while black or red phosphorus is not.

The qualifiers, associated chemicals and chemical categories, and typical applicability of these qualifiers and chemicals to the semiconductor manufacturing industry are presented below. A detailed discussion of the qualifier criteria can be found in the *TRI Forms and Instructions*.

- **Aluminum oxide (fibrous)** - Beginning with EPCRA Section 313 reports for calendar year 1989, aluminum oxide is only subject to threshold determination release, and other waste management calculations when it is handled in fibrous forms. U.S. EPA has characterized fibrous aluminum oxide for purposes of EPCRA Section 313 reporting as a man-made fiber commonly used in high-temperature insulation applications such as furnace linings, filtration, gaskets, joints, and seals.
- **Asbestos (friable)** - Asbestos only needs to be considered when it is handled in the friable form. Friable refers to the physical characteristics of being able to crumble, pulverize, or reduce to a powder with hand pressure.
- **Fume or dust** - Three metals (aluminum, vanadium, and zinc) are qualified with "fume or dust." This definition excludes "wet" forms such as solutions or slurries, but includes powder, particulate, or gaseous forms of these metals. For example, use of aluminum metal as a dopant is therefore not subject to reporting unless the aluminum is in the form of a fume or dust. However, the entire weight of all aluminum compounds should be included in the threshold determination for aluminum compounds regardless of whether the compound is a fume or dust. For semiconductor applications, aluminum is typically handled in slurry form and would not be reportable. Keep in mind that if a threshold is exceeded, only the metal portion of metal compounds is reported in release and other waste management estimates.
- **Hydrochloric acid (acid aerosols)** - On July 25, 1996, U.S. EPA promulgated a final rule delisting non-aerosol forms of hydrochloric acid (CAS Registry No. 7647-01-0) from the EPCRA Section 313 chemical list (effective for the 1995 reporting year). Therefore, threshold determinations and release and other waste management estimates now apply only to the aerosol forms. Under EPCRA Section 313, the term aerosol covers any generation of airborne acid (including mists, vapors, gas, or fog) without any particle size limitation. Therefore, any process that sprays hydrochloric acid "manufactures" hydrochloric acid aerosol.
- **Manufacturing qualifiers** - Two chemicals, saccharin and isopropyl alcohol, contain qualifiers relating to manufacture. The qualifier for saccharin means that only manufacturers of the chemical are subject to the reporting requirement. Isopropyl alcohol (IPA), a commonly used

cleaning agent in semiconductor manufacturing operations, contains a qualifier relating to manufacture. The qualifier for IPA means that only facilities that manufacture the chemical by the strong acid process are required to report. Facilities that only process or otherwise use IPA are not required to report. Thus, a facility that uses IPA as a cleaner does not need to include the quantities in threshold determination or release and other waste management calculations.

- **Nitrate Compounds (water dissociable; reportable only in aqueous solution)** - A nitrate compound is covered by this listing only when in water and if water dissociable. Although the complete weight of the nitrate compound must be used for threshold determinations for the nitrate compounds category, only the nitrate portion of the compound must be considered for release and other waste management determinations. One issue recently raised by industry is how to report nitrate compounds in wastewater and sludge that is applied to farms as a nitrogen source (either on site or off site). Although during such use nitrate compounds may be taken up by plants and cycled back into the ecosystem, U.S. EPA considers the nitrate compounds are managed as waste and should be reported as being disposed to land (either on site or off site as appropriate). U.S. EPA has published guidance for these chemicals in *List of Toxic Chemicals Within the Water Dissociable Nitrate Compounds Category and Guidance for Reporting* (EPA 745-R-96-004), which may be found in Appendix E.
- **Phosphorus (yellow or white)** - Only manufacturing, processing, or otherwise use of phosphorus in the yellow or white chemical forms require reporting. Black and red phosphorus are not subject to EPCRA Section 313 reporting.
- **Solutions (ammonia, ammonium sulfate, and ammonium nitrate)** - On June 26, 1995, U.S. EPA deleted ammonium sulfate (solution) (CAS Registry No. 7783-20-2) from the EPCRA Section 313 chemical list and qualified the listing for ammonia (CAS Registry No. 7664-41-7). The ammonia listing was modified by adding the following qualifier: "ammonia (includes anhydrous ammonia and aqueous ammonia from water dissociable salts and other sources; 10% of total aqueous ammonia is reportable under this listing)". The deletion of ammonium sulfate (solution) and the qualification of ammonia are effective as of reporting year 1994. Therefore, ammonium sulfate is no longer a reportable chemical under EPCRA Section 313. However, aqueous ammonia that is formed from the dissociation of ammonium salts (including ammonium sulfate) in water is reportable as is the aqueous ammonia generated from the dissociation of ammonium nitrate in water. You must determine the amount of aqueous ammonia generated from solubilizing these chemicals and apply it toward the threshold for ammonia. U.S. EPA has published guidance on reporting for ammonia and ammonium salts in *EPCRA Section 313 Question and Answers, Revised 1997 Version - Appendix A*,

Directive 8. Additionally, aqueous ammonium nitrate must be included in threshold determinations and the nitrate portion included for release and other waste management calculations for the nitrate compounds category. Refer to Appendix C for further guidance on reporting aqueous ammonia.

- **Sulfuric acid (acid aerosols)** - On June 26, 1995, U.S. EPA promulgated a final rule delisting non-aerosol forms of sulfuric acid (CAS Registry No. 7664-93-9) from the EPCRA Section 313 chemical list (effective for the 1994 reporting year). Therefore, threshold determinations and release and other waste management estimates now apply only to the aerosol forms. Under EPCRA Section 313, the term aerosol covers any generation of airborne acid (including mists, vapors, gas, or fog) without any particle size limitation. Therefore, any process that sprays sulfuric acid "manufactures" sulfuric acid aerosol. Refer to Appendix D for further guidance on reporting sulfuric acid aerosols.

Other reportable chemicals often used in the semiconductor manufacturing industry are glycol ethers. The glycol ethers category includes glycol ethers derived from ethylene glycol, diethylene glycol, and triethylene glycol. It does not include glycol ethers derived from propylene glycol, dipropylene glycol, or tripropylene glycol. Refer to the EPA document "Toxics Release Inventory - List of Toxic Chemicals Within the Glycol Ethers Category" (EPA-745-R-95-006) for a complete discussion, definition, and examples of chemicals that should be included in the glycol ethers category.

3.2 Step 2. Identify the Activity Category and any Exempt Activities for Each EPCRA Section 313 Chemical

The next step is to determine the activity category (or categories) and any exempt activities for each EPCRA Section 313 chemical on your list. Table 3-1 lists the reporting thresholds for each of these activity categories (Tables 3-2 through 3-4 provide detailed definitions of subcategories for each activity category). Each threshold must be individually calculated; they are mutually exclusive and are not additive.

Table 3-1

Reporting Thresholds

Activity Category	Threshold
Manufacture (including import)	25,000 pounds per year
Process	25,000 pounds per year
Otherwise use	10,000 pounds per year

Example - Threshold Determination

If your facility manufactures 22,000 pounds of an EPCRA Section 313 chemical or chemical category and you also otherwise use 8,000 pounds of the same chemical or chemical category, you have not exceeded either threshold, and an EPCRA Section 313 report for that chemical is not required. However, if your facility manufactures 28,000 pounds per year of an EPCRA Section 313 chemical or chemical category and otherwise uses 8,000 pounds of the same chemical or chemical category, you have exceeded the manufacturing threshold and ALL release and other waste management quantities (except those specifically exempted) of that chemical or chemical category must be reported on the Form R, including those from the "otherwise used" activity.

COMMON ERROR - Threshold Determination for Recirculation

Facilities often incorrectly base threshold calculations on the amount of EPCRA Section 313 chemicals in a recirculation system rather than the amount actually used in the reporting year. The amount of the EPCRA Section 313 chemical that is actually manufactured (including the quantity imported), processed, or otherwise used, not the amount in storage or in the system, should be the amount applied to the threshold determination. For example, a solvent containing an EPCRA Section 313 chemical is used, recirculated on site, and reused as a solvent. The amount of EPCRA Section 313 chemical recirculated on site in the on-site recycling process is not considered in the threshold determination because this is considered a "direct reuse" and is not reportable. Only the amount of new chemical added to the system should be included in the otherwise used threshold calculation. However, if you send a solvent containing an EPCRA Section 313 chemical or chemical category off site for distillation and subsequent recycling, it should be reported as a transfer to an off-site location for recycling (Form R, Part II, Section 6.2 and 8.5) because the distillation is considered a waste management activity. The amount of solvent returned to you and subsequently used in the same reporting year must be included in the threshold determination. If the reporting threshold is exceeded, the total quantity recycled should be reported in Section 8.4, i.e., the amount recycled must be reported in Section 8.4 each time it is recycled.

Each of the activity categories is divided into subcategories. As discussed in the *TRI Forms and Instructions*, you are required to designate EACH category and subcategory that applies to your facility. Detailed definitions, including descriptions of subcategories for each activity and examples, are presented in Tables 3-2, 3-3, and 3-4.

Table 3-2

Definitions and Examples of Manufacturing Subcategories

Manufacturing Activity Subcategory	Definition	Examples in the Semiconductor Manufacturing Industry*
Produced or imported for on-site use/processing	A chemical or chemical category that is produced or imported and then further processed or otherwise used at the same facility.	Sulfuric acid aerosols are manufactured on site for etching/cleaning operations (the acid is also otherwise used)
Produced or imported for sale/distribution	A chemical or chemical category that is produced or imported specifically for sale or distribution outside the manufacturing facility.	
Produced as a byproduct	A chemical or chemical category that is produced coincidentally during the production, processing, or otherwise use of another chemical substance or a mixture and is separated from that substance or mixture. Toxic chemicals or chemical categories produced and released as a result of waste treatment or disposal are also considered byproducts.	Nitrate compounds produced through the neutralization of nitric acid in a wastewater treatment system
Produced as an impurity	A chemical or chemical category that is produced coincidentally as a result of the manufacture, processing, or otherwise use of another chemical and remains primarily in the mixture or product with that other chemical.	

* More complete discussions of the industry-specific examples can be found in Chapter 4 of this guidance manual.

Table 3-3**Definitions and Examples of Processing Subcategories**

Processing Activity Subcategory	Definition	Examples in the Semiconductor Manufacturing Industry*
Reactant	A natural or synthetic chemical or chemical category used in chemical reactions for the manufacture of another chemical substance or product. Examples include feedstocks, raw materials, intermediates, and initiators.	
Formulation component	A chemical or chemical category that is added to a product or product mixture prior to further distribution of the product and acts as a performance enhancer during use of the product. Examples include additives, dyes, reaction diluents, initiators, solvents, inhibitors, emulsifiers, surfactants, lubricants, flame retardants, and rheological modifiers.	Arsenic or antimony compounds used as dopants
Article component	A chemical or chemical category that becomes an integral component of an article distributed for industrial, trade, or consumer use.	Lead may be used as solder or frame for the final chip assembly
Repackaging only	A chemical or chemical category that is processed or prepared for distribution in commerce in a different form, state, or quantity. May include, but is not limited to, the transfer of material from a bulk container, such as a tank truck, to smaller containers such as cans or bottles.	

* More complete discussions of the industry-specific examples can be found in Chapter 4 of this guidance manual.

Table 3-4

Definitions and Examples of Otherwise Use Subcategories

Otherwise Use Activity Subcategory	Definition	Examples in the Semiconductor Manufacturing Industry*
Chemical processing aid	A chemical or chemical category that is added to a reaction mixture to aid in the manufacture or synthesis of another chemical substance but is not intended to remain in or become part of the product or product mixture. Examples include process solvents, catalysts, inhibitors, initiators, reaction terminators, and solution buffers.	Chlorine used for water treatment or etching
Manufacturing aid	A chemical or chemical category that aids the manufacturing process but does not become part of the resulting product and is not added to the reaction mixture during the manufacture or synthesis of another chemical substance. Examples include process lubricants, metalworking fluids, coolants, refrigerants, and hydraulic fluids.	
Ancillary or other use	A chemical or chemical category that is used for purposes other than aiding chemical processing or manufacturing. Examples include cleaners, degreasers, lubricants, fuels (including waste fuels), and chemicals used for treating wastes.	The majority of the chemicals reported to TRI for the semiconductor industry fall under this definition, primarily solvents and acids used for etching and cleaning

* More complete discussions of the industry-specific examples can be found in Chapter 4 of this guidance manual.

3.2.1 Concentration Ranges for Threshold Determination

You are required to use the best readily available information for all calculations in EPCRA reporting; however, the exact concentration of an EPCRA Section 313 chemical in a mixture or trade name product may not be known. The supplier or MSDS may only list ranges, or upper or lower bound concentrations. U.S. EPA has developed guidance on how to use information in this situation for threshold determinations.

- If the concentration is provided as a lower and upper bound or as a range, you should use the mid-point in your calculations for the threshold determination. For example, the MSDS for the trade name product states methanol is present in a concentration of not less than 20% and not more than 40%, or it may be stated as present at a concentration between 20 to

40%. You should use the mid-point value of 30% methanol in your threshold calculations.

- If only the lower bound concentration of the EPCRA Section 313 chemical or chemical category is specified and the concentration of other components are given, subtract the other component values from 100%. The remainder should be considered the upper bound for the EPCRA Section 313 chemical or chemical category and you should use the given lower bound to calculate the mid-point as discussed above. For example, the MSDS states that a solvent contains at least 50% methyl ethyl ketone and 20% non-hazardous surfactants. Subtracting the non-hazardous contents from 100% leaves 80% as the upper bound for MEK. The mid-point between upper (80%) and lower (50%) bounds is 65%, the value you should use in your threshold calculation.
- If only the lower bound is specified and no information on other components is given assume the upper bound is 100% and calculate the mid-point as above.
- If only the upper bound concentration is provided you must use this value in your threshold calculation.

Special guidance for concentration ranges that straddle the *de minimis* value is presented in Section 3.2.2.1.

3.2.2 Evaluation of Exemptions

When determining thresholds, you can exclude quantities of any EPCRA Section 313 chemicals and chemical categories that are manufactured, processed, or otherwise used in exempt activities. Exemptions are divided into four classes:

1. *De minimis* exemption;
2. Article exemption;
3. Facility-related exemption; and
4. Activity-related exemptions.

COMMON ERROR - Exempt Activities

If an EPCRA Section 313 chemical or chemical category is used in exempt activities, the quantity used in these activities does not need to be included in your threshold or release and other waste management calculations, even if the chemical or chemical category is used in a reportable activity elsewhere in the facility.

3.2.2.1 *De Minimis* Exemption

If the amount of EPCRA Section 313 chemical(s) or chemical categories present in a mixture or trade name product processed or otherwise used is below its *de minimis* concentration level, that amount is considered to be exempt from threshold determinations and release and other waste management calculations (note that this exemption does not apply to manufacturing, except for importation or as an impurity as discussed below). The *de minimis* concentration for EPCRA Section 313 chemicals and chemical categories is 1%, except for Occupational Safety and Health Administration (OSHA)-defined carcinogens, which have a 0.1% *de minimis* concentration. Note that if a mixture contains more than one member of an EPCRA Section 313 compound category, the weight percent of all members must be summed. If the total meets or exceeds the category's *de minimis* level, the *de minimis* exemption does not apply. U.S. EPA has published several detailed questions and answers and a directive in the current edition of *EPCRA Section 313 Questions and Answers* (1998 edition is EPA 745-B-98-004; see Appendix A, Directive #2) that may be helpful if you have additional concerns about the *de minimis* exemption. The *TRI Forms and Instructions* list each EPCRA Section 313 chemical and compound category with the associated *de minimis* value.

Example - *De Minimis*

Your facility processes a mixture containing 1.1% nitric acid and 0.6% manganese. The *de minimis* exemption would apply to manganese because the concentration is below 1%; however, it would not apply to nitric acid. All of the nitric acid must be included in threshold determinations, and release and other waste management calculations.

The *de minimis* exemption also applies to EPCRA Section 313 chemicals and chemical categories that are coincidentally manufactured below the *de minimis* level as an impurity in a mixture and subsequently distributed in commerce. In addition, the exemption applies to EPCRA Section 313 chemicals and chemical categories below the *de minimis* concentration in an imported mixture or trade name product.

For some mixtures the concentration of EPCRA Section 313 chemicals and chemical categories may be available only as a range. U.S. EPA has developed guidance on how

to determine quantities applicable to threshold determinations and release and other waste management calculations when this range straddles the *de minimis* value. In general, only the quantity of the processed or otherwise used EPCRA Section 313 chemical or chemical category whose concentration exceeds the *de minimis* must be considered. Therefore, U.S. EPA allows facilities to estimate the quantity below the *de minimis* and exclude it from further consideration. The following examples illustrate this point.

Examples - Concentration Ranges Straddling the *De Minimis* Value

A facility processes 8,000,000 pounds of a mixture containing 0.2 to 1.2% manganese. Manganese is subject to a 1% *de minimis* concentration exemption. The amount of mixture subject to reporting is equal to the total quantity of mixture multiplied by the percentage of the manganese concentration range above the *de minimis* concentration. The amount at or above *de minimis* is calculated as:

$$(0.012 - 0.009) \div (0.012 - 0.002)$$

Therefore, the amount of the mixture that is subject to threshold determination and release and other waste management estimates is:

$$(8,000,000) \times ((0.012 - 0.009) \div (0.012 - 0.002))$$

The average concentration of manganese that is not exempt (at or above the *de minimis*) is:

$$(0.012 + 0.01) \div (2.00)$$

Therefore, the amount of manganese that is subject to threshold determination and release and other waste management estimates is:

$$\left[\frac{(8,000,000) (0.012 - 0.009)}{(0.012 - 0.002)} \right] \left[\frac{(0.012 + 0.01)}{2.00} \right]$$

$$= 26,400 \text{ lb manganese (which is above the processing threshold)}$$

In this example, because the facility's information pertaining to manganese was available to one decimal place, 0.9 was used to determine the amount at or above the *de minimis* concentration. If the information was available to two decimal places, 0.99 should be used.

The exemption does not apply to EPCRA Section 313 chemicals and chemical categories coincidentally manufactured as byproducts and separated from the product, nor does it apply to EPCRA Section 313 chemicals and chemical categories coincidentally manufactured as a result of waste management activities, from either on site or off site. (Under EPCRA Section 313, U.S. EPA does not consider waste to be a mixture.) For example, many facilities treat waste solvents by incinerating them. If coal is used as the primary fuel source to incinerate these waste

solvents, combustion can result in the coincidental manufacture of sulfuric and hydrochloric acid aerosols and metal compounds. Since the *de minimis* exemption does not apply to the coincidental manufacture of EPCRA Section 313 chemicals or chemical categories as a by-product or in a waste treatment process, the formation of these compounds must be considered for threshold determinations and release and other waste management calculations.

Once the *de minimis* level has been equaled or exceeded, the exemption no longer applies to that process stream, even if the EPCRA Section 313 chemical or chemical category later falls below the *de minimis* concentration. All release and other waste management activities that occur after the *de minimis* concentration has been equaled or exceeded are subject to reporting. The facility does not have to report release and other waste management activities that took place before the *de minimis* concentration was equaled or exceeded.

3.2.2.2 Article Exemption

An article is defined as a manufactured item that:

- Is formed to a specific shape or design during manufacture;
- Has end-use functions dependent in whole or in part upon its shape or design; and
- Does not release an EPCRA Section 313 chemical or chemical category under normal conditions of processing or otherwise use of the item at the facility.

If you receive a manufactured article from another facility and process or otherwise use it without changing the shape or design, and your processing or otherwise use does not result in the release of more than 0.5 pound of the EPCRA Section 313 chemical or chemical category in a reporting year from all like articles, then the EPCRA Section 313 chemical or chemical category in that article is exempt from threshold determinations and release and other waste management reporting.

The shape and design can be changed somewhat during processing and otherwise use as long as part of the item retains the original dimensions. That is, as a result of processing or otherwise use, if an item retains its initial thickness or diameter, in whole or in part, then it

still meets the article definition. If the item's original dimensional characteristics are totally altered during processing or otherwise use, the item would not meet the definition. As an example, items that do not meet the definition would be items that are cold extruded, such as lead ingots formed into wire or rods. However, cutting a manufactured item into pieces that are recognizable as the article would not change the exemption status as long as the diameter and the thickness of the item remain unchanged. For instance, metal wire may be bent and sheet metal may be cut, punched, stamped, or pressed without losing the article status as long as no change is made in the diameter of the wire or tubing or the thickness of the sheet and no releases above 0.5 pound per year occur.

Any processing or otherwise use of an article that results in a release above 0.5 pound per year for each EPCRA Section 313 chemical or chemical category for all like articles negates the exemption. Cutting, grinding, melting, or other processing of a manufactured item could result in a release of an EPCRA Section 313 chemical or chemical category during normal conditions of use and, therefore, could negate the article exemption if the total releases exceed 0.5 pound in a year. However, if all of the resulting waste is recycled or reused, either on site or off site so the release and other waste management of the EPCRA Section 313 chemical or chemical category does not exceed 0.5 pound, then the article's exemption status is maintained. Also, if the processing or otherwise use of similar manufactured items results in a total release and other waste management of less than or equal to 0.5 pound of any individual EPCRA Section 313 chemical or chemical category to any environmental media in a calendar year, U.S. EPA will allow this quantity to be rounded to zero and the manufactured items to maintain their article exemption. The 0.5-pound limit does not apply to each individual article, but applies to the sum of all release and other waste management activities from processing or otherwise use of like articles for each EPCRA Section 313 chemical or chemical category. The current edition of *EPCRA Section 313 Questions and Answers* (1998 edition is EPA 745-B-98-004) presents several specific question and answer discussions pertaining to the article exemption.

Example - Article Exemption

If an article, as part of a coating pre-treatment operation, is subjected to an etching process that removes a portion of an EPCRA Section 313 metal from the surface that is not recycled or reused, this process would constitute a release and negate the article exemption. For example, a copper plate is cleansed by dipping in a sulfuric acid solution. Some of the copper reacts with the acid to form copper sulfate and the used cleaning solution is discharged to a POTW. This process is considered a release of the copper and, if the release is greater than 0.5 pound per year, the plate has lost its article exemption.

3.2.2.3 Facility-Related Exemption

Laboratory Exemption

EPCRA Section 313 chemicals and chemical categories that are manufactured, processed, or otherwise used in laboratories under supervision of a technically qualified individual are exempted from the threshold determination (and subsequent release and other waste management calculations). This exemption may be applicable in circumstances such as laboratory sampling and analysis, research and development, and quality assurance and quality control activities. It does not include pilot plant scale or specialty chemical production. It also does not include laboratory support activities. For example, chemicals used to maintain laboratory equipment are not eligible for the laboratory exemption.

3.2.2.4 Activity-Related Exemptions

Some exemptions apply to the "otherwise use" of a toxic chemical. The specific quantities of EPCRA Section 313 chemicals used in these activities do not need to be included in a facility's threshold determination (nor the associated release and other waste management calculations). The following activities are considered exempt:

- **EPCRA Section 313 chemicals and chemical categories used in routine janitorial or facility grounds maintenance.** Examples are bathroom cleaners, fertilizers, and garden pesticides similar in type or concentration found in consumer products. Materials used to clean process equipment do not meet this exemption.
- **Personal use of items.** Examples are foods, drugs, cosmetics, and other personal items including those items within the facility such as in a facility

operated cafeteria, store, or infirmary. Office supplies such as correction fluid are also exempt.

Example - Personal Use Exemption

Ammonia used to clean a cafeteria grill is exempt from threshold determinations and release and other waste management calculations.

- **Structural components of the facility.** Exemptions apply to EPCRA Section 313 chemicals and chemical categories present in materials used to construct, repair, or maintain structural components of a facility. An example common to all facilities would be the solvents and pigments used to paint the buildings. Materials used to construct, repair, or maintain process equipment are not exempt.
- **EPCRA Section 313 chemicals and chemical categories used with facility motor vehicles.** This category includes the use of EPCRA Section 313 chemicals and chemical categories for the purpose of maintaining motor vehicles operated by the facility. Common examples include gasoline, radiator coolant, windshield wiper fluid, brake and transmission fluid, oils and lubricants, cleaning solutions, and solvents in paint used to touch up the vehicle. Motor vehicles include cars, trucks, forklifts, locomotives, and aircraft. Note that this exemption applies to the OTHERWISE USE of EPCRA Section 313 chemical and chemical categories. The coincidental manufacture of EPCRA Section 313 chemicals and chemical categories resulting from combustion of gasoline is not exempt and should be considered as part of the manufacturing threshold.

Example - Motor Vehicle Exemption

Methanol is purchased for use as a processing aid and as a windshield washer anti-freeze in company vehicles. The amount used for the latter purpose would be subtracted from the facility total **BEFORE** the facility total is compared to the activity threshold. Even if the facility still exceeds the otherwise use threshold, the amount in the anti-freeze is exempt from release and other waste management reporting.

This exemption does NOT apply to stationary equipment. The use of lubricants and fuels for stationary process equipment (e.g., pumps and compressors) and stationary energy sources (e.g., furnaces, boilers, heaters) are NOT exempt.

Example - Process Equipment Chemical Use

Lubricants containing listed EPCRA Section 313 chemicals and chemical categories used on facility vehicles or on-site structural maintenance activities that are not integral to the process are exempt activities. However, lubricants used to maintain pumps and compressors that aid facility process operations are not exempt and the amount of the EPCRA Section 313 chemical in the lubricant should be applied to the otherwise use threshold.

- **EPCRA Section 313 chemicals and chemical categories in certain air or water drawn from the environment or municipal sources.** Included are EPCRA Section 313 chemicals and chemical categories present in process water and non-contact cooling water drawn from the environment or a municipal source, or chemicals and chemical categories present in air used either as compressed air or as an oxygen source for combustion.

Example - Chemicals in Process Water

A facility uses river water for one of its processes. This water contains approximately 100 pounds of an EPCRA Section 313 chemical or chemical category. The facility ultimately returns the water that contains the entire 100 pounds of the EPCRA Section 313 chemical or chemical category to the river. The EPCRA Section 313 chemical or chemical category in the water can be considered exempt because the EPCRA Section 313 toxic chemical was present as it was drawn from the environment. The facility does not need to consider the EPCRA Section 313 chemical or chemical category drawn with river water for threshold determinations or release and other waste management reporting.

3.2.3 Additional Guidance on Threshold Calculations for Certain Activities

This section covers three specific situations in which the threshold determination may vary from normal facility operations: reuse, remediation, and recycling activities of EPCRA Section 313 chemicals and chemical categories.

3.2.3.1 Reuse Activities

Threshold determinations of EPCRA Section 313 chemicals or chemical categories that are reused at the facility are based only on the amount of the EPCRA Section 313 chemical or chemical category that is added to the system during the year, not the total volume in the system. For example, a facility operates a refrigeration unit that contains 15,000 pounds of anhydrous ammonia at the beginning of the year. The system is charged with 2,000 pounds of anhydrous ammonia during the year. The facility has therefore otherwise used only 2,000

pounds of the EPCRA Section 313 chemical or chemical category and is not required to report (unless the facility has additional otherwise use activities of ammonia that, when taken together, exceed the reporting threshold). If, however, the whole refrigeration unit was recharged with 15,000 pounds of new or fresh anhydrous ammonia during the year, the facility would exceed the otherwise use threshold, and be required to report.

3.2.3.2 Remediation Activities

EPCRA Section 313 chemicals and chemical categories undergoing remediation (e.g., Superfund remediation) are not being manufactured, processed, or otherwise used. Therefore, they are not included in the activity threshold determinations.

However, if you are conducting remediation of an EPCRA Section 313 chemical or chemical category that is also being manufactured, processed, or otherwise used by the facility above an activity threshold level, you must consider this activity for release and other waste management calculations. You must report any release or other waste management quantities of an EPCRA Section 313 chemical or chemical category due to remediation in Part II, Sections 5 through 8, accordingly, of the Form R. Those quantities would also be considered as part of the amount for determining Form A eligibility. EPCRA Section 313 chemicals and chemical categories used for remediation should be considered toward threshold determinations. If an EPCRA Section 313 chemical or chemical category exceeds one of the reporting thresholds elsewhere at the facility, all release and other waste management quantities of that chemical or chemical category must be reported, including release and other waste management quantities resulting from remediation.

Excavation of material already landfilled does not constitute a release or other waste management activity for EPCRA Section 313 reporting purposes. Routine activities (e.g., dredging a lagoon), even if not performed every year, are not considered to be remedial actions and are always subject to reporting.

3.2.3.3 Recycling Activities

For on-site recycling and reuse systems, where the same EPCRA Section 313 chemical or chemical category is recycled and reused multiple times, the recycled quantity should be counted only once for threshold calculations. (Please note that for reporting on-site waste management activities [Section 8 of Form R] the quantity of the EPCRA Section 313 chemical should be counted every time it exits the recycling unit.) EPCRA Section 313 chemicals and chemical categories recycled off site and returned to the facility should be treated as newly purchased materials for EPCRA Section 313 threshold determination.

3.3 **Step 3. Calculate the Quantity of Each EPCRA Section 313 Chemical and Chemical Category and Determine Which Ones Exceed an Activity Threshold**

The final step is to determine the quantity and which EPCRA Section 313 chemicals and chemical categories exceed an activity threshold. At this point you should have:

1. Identified each EPCRA Section 313 chemical and chemical category at your facility.
2. Determined the activity category for each EPCRA Section 313 chemical and chemical category (manufactured, processed, or otherwise used).

Now, you must sum the usage for each EPCRA Section 313 chemical and chemical category by activity category, subtract all exempt quantities, and compare the totals to the applicable thresholds. Each EPCRA Section 313 chemical and chemical category exceeding any one of the activity thresholds requires the submission of an EPCRA Section 313 report. Provided you meet certain criteria you may prepare a Form A rather than a Form R (see Section 2.8).

COMMON ERROR - Assuming a Threshold is Exceeded.

U.S. EPA recently published a report, "The 1994 and 1995 Toxic Release Inventory Data Quality Report," EPA 745-R-98-002, with the site survey results of over 100 facilities to evaluate EPCRA Section 313 reporting quality. One of the findings of this survey was that facilities that simply assumed that chemical activity thresholds were exceeded were often in error. This resulted in many of these facilities filing EPCRA Section 313 reports when thresholds were actually not exceeded. Unless the facility has strong grounds to support such an assumption, the time spent in explicitly calculating the activity threshold is well spent.

COMMON ERROR - What if Your Facility Has No Release and other Waste Management Quantities of EPCRA Section 313 Chemicals?

If you meet all reporting criteria and exceed any threshold for an EPCRA Section 313 chemical or chemical category, you must file an EPCRA Section 313 report for that chemical or chemical category, even if you have zero release and other waste management activities. Exceeding the chemical activity threshold, not the quantity released and otherwise managed as waste determines whether you must report. Note that if the release and other waste managed quantity is 500 pounds or less you may be eligible to use the alternate certification statement, Form A rather than a Form R (see Section 2-8).

To determine if an EPCRA Section 313 chemical or chemical category exceeds a reporting threshold, you must calculate the annual activity amount of that chemical. Start with the amount of chemical or chemical category at the facility as of January 1, add any amounts brought on site during the year and the amount manufactured (including imported), and subtract the amount left in the inventory on December 31. If necessary, adjust the total to account for exempt activities (see Section 3.2.2 for a discussion of exemptions). You should then compare the result to the appropriate threshold to determine if you are required to submit an EPCRA Section 313 report for that chemical or chemical category. Keep in mind that the threshold calculations are independent for each activity category: manufactured, processed, and otherwise used. If more than one activity category applies, the amount associated with each category is determined separately.

Table 3-5 presents a work sheet that may be helpful when conducting your threshold determinations. Table 3-6 illustrates an example of how the work sheet can be used for the following example:

Example - Threshold Worksheet

Assume your facility purchases two mixtures that contain xylene in the applicable reporting year. You purchased 25,000 pounds of Mixture A (which is 50% xylene according to the MSDS) and 110,000 pounds of Mixture B (which contains 20% xylene). Further, you determine that you process the entire quantity of Mixture A, while you process only half of Mixture B and otherwise use the other half. You do not qualify for any exempt activities.

In this example, you would have processed a total of 23,500 pounds of xylene (12,500 pounds from activities associated with Mixture A and 11,000 pounds from activities associated with Mixture B). You would also have otherwise used a total of 11,000 pounds (all from Mixture B). Therefore, you would not have exceeded the 25,000 pound threshold for processing; however, you would have exceeded the 10,000 pound threshold for otherwise use and would be required to submit an EPCRA Section 313 report that includes release and other waste managed quantities from all activities (including processing).

Table 3-5. EPCRA Section 313 Reporting Threshold Worksheet

Facility Name: _____

EPCRA Section 313 Chemical or Chemical Category: _____

CAS Registry Number: _____

Reporting Year: _____

Date Worksheet Prepared: _____

Prepared By: _____

Amounts of chemical or chemical category manufactured, processed, or otherwise used.

Mixture Name or Other Identifier	Information Source	Total Weight (lb)	Percent TRI Chemical by Weight	TRI Chemical Weight (lb)	Amount of the EPCRA Section 313 Chemical by Activity (lb):		
					Manufactured	Processed	Otherwise Used
1.							
2.							
3.							
4.							
Subtotal:					(A) _____ lb.	(B) _____ lb.	(C) _____ lb.

Exempt quantity of chemical or chemical category that should be excluded.

Mixture Name as Listed Above	Applicable Exemption (de minimis, article, facility, activity)	Fraction or Percent Exempt (if Applicable)	Amount of the EPCRA Section 313 Chemical Exempt from Above (lb):		
			Manufactured	Processed	Otherwise Used
1.					
2.					
3.					
4.					
Subtotal:			(A) _____ lb.	(B) _____ lb.	(C) _____ lb.

Amount subject to threshold: (A-A₁) _____ lb. (B-B₁) _____ lb. (C-C₁) _____ lb.

Compare to threshold for EPCRA Section 313 reporting.

Activity threshold quantities: 25,000 lb. 25,000 lb. 10,000 lb.

If any one of the thresholds is exceeded, reporting is required for all activities. [Do not submit this worksheet with Form R, retain it for your records.]

Table 3-6. Sample EPCRA Section 313 Reporting Threshold Worksheet

Facility Name: ABC Semiconductor Corporation

Date Worksheet Prepared: May 1, 1998

EPCRA Section 313 Chemical or Chemical Category: Xylene (mixed isomers)

Prepared By: A.B. Calloway

CAS Registry Number: 1330-20-7

Reporting Year: 1997

Amounts of chemical or chemical category manufactured, processed, or otherwise used.

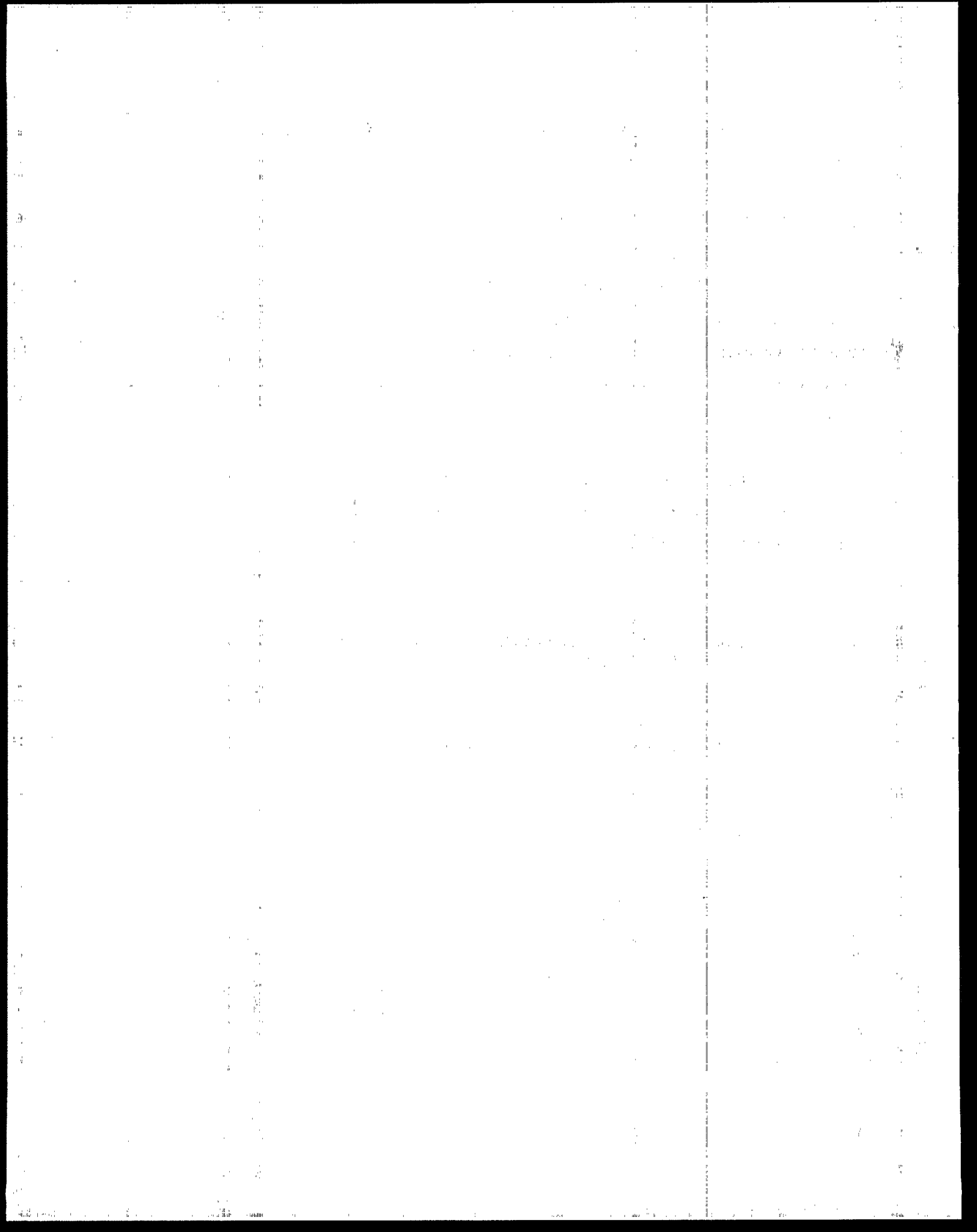
Mixture Name or Other Identifier	Information Source	Total Weight (lb)	Percent TRI Chemical by Weight	TRI Chemical Weight (lb)	Amount of the EPCRA Section 313 Chemical by Activity (lb):		
					Manufactured	Processed	Otherwise Used
1. Mixture A	MSDS	25,000	50%	12,500	---	12,500	---
2. Mixture B	MSDS	110,000	20%	22,000	---	11,000	11,000
3.							
4.							
Subtotal:					(A) 0 lb.	(B) 23,500 lb.	(C) 11,000 lb.

Exempt quantity of chemical or chemical category that should be excluded.

Mixture Name as Listed Above	Applicable Exemption (de minimis, article, facility, activity)	Fraction or Percent Exempt (if Applicable)	Amount of the EPCRA Section 313 Chemical Exempt from Above (lb):		
			Manufactured	Processed	Otherwise Used
1. Mixture A	none				
2. Mixture B	none				
3.					
4.					
Subtotal:			(A ₁) 0 lb.	(B ₁) 0 lb.	(C ₁) 0 lb.
Amount subject to threshold:			(A-A ₁) 0 lb.	(B-B ₁) 23,500 lb.	(C-C ₁) 11,000 lb.
Activity threshold quantities:			25,000 lb.	25,000 lb.	10,000 lb.

Compare to threshold for EPCRA Section 313 reporting.

If any one of three thresholds is exceeded, reporting is required for all activities. [Do not submit this worksheet with Form R, retain it for your records.]



CHAPTER 4 - ESTIMATING RELEASE AND OTHER WASTE MANAGEMENT QUANTITIES

4.0 PURPOSE

This chapter is intended to guide the user in developing a systematic approach for estimating quantities of EPCRA Section 313 chemicals and chemical categories released and otherwise managed as waste from semiconductor manufacturing operations. Figure 4-1 diagrams a recommended approach for estimating quantities of reportable EPCRA Section 313 chemicals or chemical categories.

This chapter also includes common EPCRA Section 313 reporting and compliance issues as they apply to the semiconductor manufacturing industry. The general discussion (Section 4.1) is followed by a presentation of specific examples and issues (Section 4.2).

4.1 General Steps for Determining Release and Other Waste Management Activity Quantities

Release and other waste management activity quantities can be determined by completing the following four steps, described in detail in the following sections.

- | | |
|----------------|--|
| Step 1) | Prepare a process flow diagram . |
| Step 2) | Identify EPCRA Section 313 chemicals and chemical categories and potential sources of chemical release and other waste management activities. |
| Step 3) | Identify release and other waste management activity types . |
| Step 4) | Determine the most appropriate method(s) and calculate the estimates for release and other waste management activity quantities. |

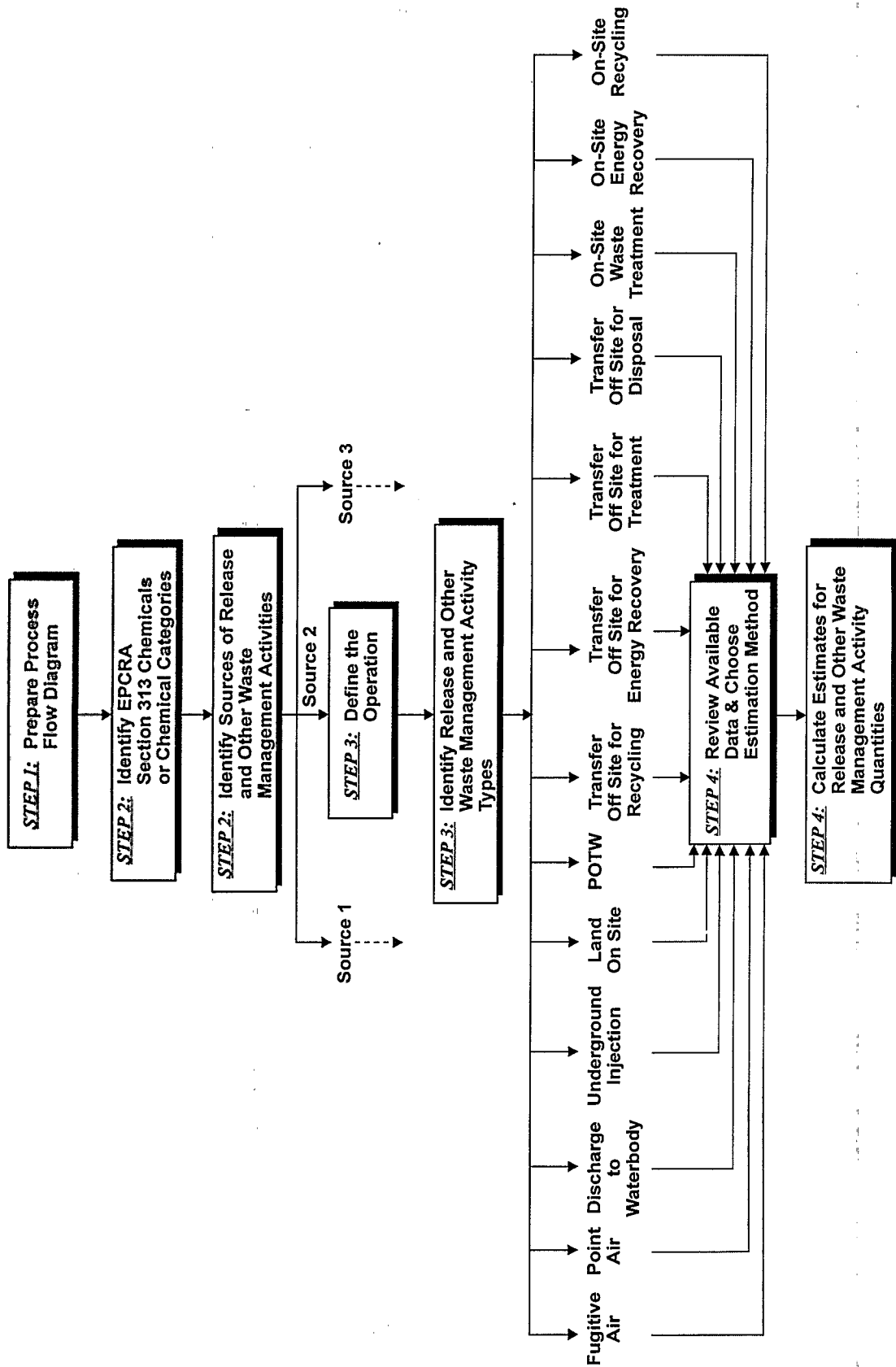


Figure 4-1. Release and Other Waste Management Activity Calculation Approach

For EPCRA Section 313 purposes, "sources" means the streams or units that generate the release and other waste management activity (such as process vents, container residue, or spills) and "types" means the environmental media corresponding to elements in Section 5 through 8 of the 1997 Form R (for example, releases to fugitive air, releases to stack air, discharges to receiving streams or POTWs, or releases to land).

4.1.1 Step 1: Prepare a Process Flow Diagram

Preparing a process flow diagram will help you to identify potential sources of EPCRA Section 313 chemicals and chemical categories released and otherwise managed as waste at your facility. Depending on the complexity of your facility, you may want to diagram individual processes or operations rather than the entire facility. The diagram should show how materials flow through the processes and identify material input, generation, and output points. Looking at each operation separately, you can determine where EPCRA Section 313 chemicals and chemical categories are used and the medium to which they may be released or otherwise managed as waste.

4.1.2 Step 2: Identify EPCRA Section 313 Chemicals and Chemical Categories and Potential Sources of Chemical Release and Other Waste Management Activities

Once a process flow diagram has been developed, you must determine the potential sources and the EPCRA Section 313 chemicals and chemical categories that may be released and otherwise managed as waste from each unit operation and process. Remember to include upsets and routine maintenance activities. Potential sources include:

- Accidental spills and releases;
- Clean up and housekeeping practices;
- Combustion byproducts;
- Container residues;
- Fittings;
- Flanges;
- Process discharge stream;
- Process vents
- Pumps;
- Recycling and energy recovery byproducts;
- Relief valves;
- Stock pile losses;
- Storage tanks;
- Storm water runoff;
- Tower stacks;
- Transfer operations;
- Treatment sludge;

- Volatilization from process or treatment; and
- Waste treatment discharges.

Next, you must identify the EPCRA Section 313 chemicals and chemical categories that may be released or otherwise managed as waste from each source. A thorough knowledge of the facility operations and processes is required for this determination. You should also consider whether any of the EPCRA Section 313 chemicals or chemical categories are coincidentally manufactured at your facility. Table 2-2 identifies EPCRA Section 313 chemicals and chemical categories typically used in the operations common to semiconductor manufacturing operations. This table can be used as an aid in identifying which chemicals and chemical categories are found in your process. The list may not include all the EPCRA Section 313 chemicals and chemical categories your facility uses, and it may include many chemicals and chemical categories that you do not use.

4.1.3 Step 3: Identify Release and Other Waste Management Activity Types

For each identified source of an EPCRA Section 313 chemical or chemical category, you should examine all possible release and other waste management activity types. Figure 4-2 schematically represents the possible release and other waste management activity types as they correspond to individual data elements of the Form R. Remember to include both routine operations and accidents when identifying types. This diagram along with the following descriptions can be used as a checklist to make sure all possible types of release and other waste management activities have been considered.

- a. **Fugitive or Non-Point Air Emissions (Part II, Section 5.1 of Form R) -**
 - Includes all emissions to the air that are not released through stacks, vents, ducts, pipes, or any confined air stream. Examples include:
 - Equipment leaks from valves, pump seals, flanges, compressors, sampling connections, open-ended lines, etc.;

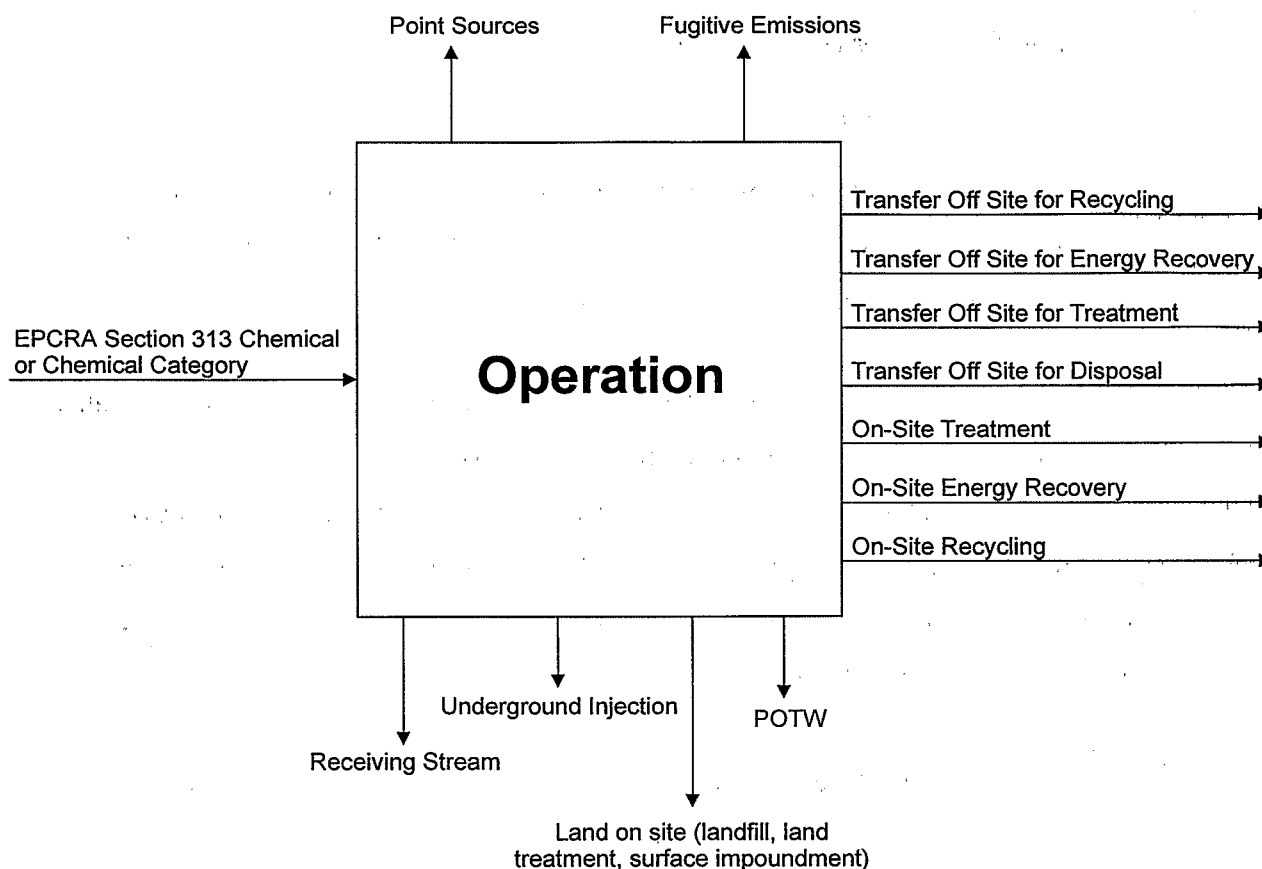


Figure 4-2. Possible Release and Other Waste Management Activity Types for EPCRA Section 313 Chemicals and Chemical Categories

- Releases from building ventilation systems, such as a roof fan in an open room;
- Evaporative losses from solvent cleaning tanks, surface impoundments, and spills; and
- Emissions from any other fugitive or non-point source.

b. Stack or Point Air Emissions (Part II, Section 5.2 of Form R) -

Includes all emissions to the air that occur through stacks, vents, ducts, pipes, or any confined air stream, including the emissions from storage tanks and air pollution control equipment. Air emissions from semiconductor manufacturing operations are often channeled through air pollution control devices. These are considered stack emissions. Note that emissions released from general room air through a ventilation system are not considered stack or point releases for the purpose of EPCRA Section 313 reporting unless they are channeled through an air pollution control device. Instead, they are considered fugitive releases. However, you should note that for certain state reporting requirements not associated

with EPCRA Section 313 reporting, some state air quality agencies consider ventilation systems to be a stack or point source.

- c. **Discharges to Receiving Streams or Water Bodies (Part II, Section 5.3 of Form R)** - Includes direct wastewater discharges to a receiving stream or surface water body. Discharges usually occur under a NPDES or SPDES permit.
- d. **Underground Injection On-Site to Class I Wells (Part II, Section 5.4.1 of Form R) and to Class II through V Wells (Part II, Section 5.4.2 of Form R)** - Includes releases into an underground well at the facility. These wells may be monitored under an Underground Injection Control (UIC) Program permit. RCRA Hazardous Waste Generator Reports may be a good source of information for wastes injected into a Class I well. Injection rate meters may provide information for all the well classes.
- e. **Disposal to Land On-Site (Part II, Section 5.5 of Form R)** - Includes all releases to land on-site, both planned (i.e., disposal) and unplanned (i.e., accidental release or spill). The four predefined subcategories for reporting quantities released to land within the boundaries of the facility are:
 - (1) **Landfill** - The landfill may be either a RCRA permitted (Part II, Section 5.5.1A) or a non-hazardous waste landfill (Part II, Section 5.5.1B). Both types are included if they are located on site. Leaks from landfills in the years subsequent to the disposal of the EPCRA Section 313 chemicals or chemical categories in the landfill do not need to be reported as a release.
 - (2) **Land treatment/application farming** - Land treatment is a disposal method in which a waste containing an EPCRA Section 313 chemical or chemical category is applied to or incorporated into soil. Volatilization of an EPCRA Section 313 chemical or chemical category because of the disposal operation must be included in the total fugitive air releases and should be excluded from land treatment/application farming to avoid double counting.

Sludge and/or aqueous solutions that contain biomass and other organic materials are often collected and applied to farm land. This procedure supplies a nitrogen source for plants and supplies metabolites for microorganisms. U.S. EPA considers this operation to be land treatment/farming if it occurs on site. If a facility sends this material off site for the same purpose, it is considered to be a "transfer to an off-site location, disposal" and should be reported under Sections 6.2 and 8.1 of the Form R.

The ultimate disposition of the chemical or chemical category after application to the land does not change the required reporting. For example, even if the chemical or chemical category is eventually biodegraded by microorganisms or plants, it is not considered recycled, reused, or treated.

- (3) **Surface impoundment** - A surface impoundment is a natural topographic depression, man-made excavation, or diked area formed primarily of earthen materials that is designed to hold an accumulation of wastes containing free liquids. Examples include: holding, settling, storage, and elevation pits; ponds; and lagoons. Quantities of the toxic chemical released to surface impoundments that are used merely as part of a wastewater treatment process generally must not be reported in this section. However, if the sludge from the surface impoundment contains the EPCRA Section 313 chemical or chemical category, then the EPCRA Section 313 chemicals or chemical categories in the sludge must be estimated in this section unless the sludge is removed and subject to another waste management activity.
- (4) **Other disposal** - Releases to land that do not fit the categories of landfills, land treatment, or surface impoundment are classified as other disposal. This disposal may include any spills or leaks of the EPCRA Section 313 chemical or chemical category to land.

- f. **Transfers Off Site to a Publicly Owned Treatment Works (POTW) (Part II, Section 6.1 of Form R)** - Includes the amount of EPCRA Section 313 chemical or chemical category in water transferred to an off-site POTW. Note that metals and metal compounds transferred to a POTW must also be reported in Section 8.1.
- g. **Transfers to Other Off-Site Locations (Part II, Section 6.2 of Form R)** - Includes all off-site transfers containing the EPCRA Section 313 chemical or chemical category for the purposes of disposal waste treatment, energy recovery, or recycling. Off-site transfer for disposal includes underground injection, landfill/surface impoundment, other land disposal and transfer to a waste broker for disposal. The amount transferred off site for disposal must also be reported in Section 8.1.

Also reported in Section 6.2 would be any residual EPCRA Section 313 chemicals in "empty" containers transferred off site. U.S. EPA expects that all containers (bags, totes, drums, tank trucks, etc.) will have a small amount of residual solids and/or liquid. On-site cleaning of containers must be considered for EPCRA Section 313 reporting. If the cleaning occurs with a solvent (organic or aqueous), you must report the disposition of the waste solvent as appropriate. If the containers are sent off site for

disposal or reclamation, you should report the EPCRA Section 313 chemical or chemical category in this section.

COMMON ERROR - Shipping Container Residue

Do not overlook residual chemicals or chemical categories in containers. U.S. EPA recently published *The 1994 and 1995 Toxic Release Inventory Data Quality Report*, EPA 745-R-98-002, presenting the site survey results of over 100 facilities to evaluate EPCRA Section 313 reporting quality. This survey found the largest source of overlooked release and other waste management activities was from container residue. So-called "empty" drums may contain an inch or more of liquid after draining and similarly "empty" bags may contain residues of dust and powder. Even though each individual drum or bag may only contain a small amount of an EPCRA Section 313 chemical or chemical category, for facilities that receive hundreds or thousands of drums or bags each year the annual cumulative amount of an EPCRA Section 313 chemical or chemical category can be substantial. The quantities should typically be reported in Section 6.2 (see Table 4-1 for estimates of liquid drum residual and the discussion in the text of this section for estimates of residual from solids).

Actual data and a knowledge of the unloading methods at your facility can be used to estimate the quantity of residual EPCRA Section 313 chemicals or chemical categories in containers. However, U.S. EPA has developed guidance to assist facilities if no site-specific information is available. Table 4-1 provides results from a study of liquid residue quantities left in drums and tanks when emptied. These results are presented as the mass percent of the vessel capacity, and are categorized based on unloading method, vessel material, and bulk fluid material properties such as viscosity and surface tension. No testing was conducted for residual solids in this study. If data on site-specific knowledge is available to estimate the quantity of solid residual in containers it should be considered. If no data are available, U.S. EPA believes an estimate of 1% residual solid is reasonable.

Table 4-1

**Summary of Liquid Residue Quantities From
Pilot-Scale Experimental Study^{a,b}
(weight percent of drum capacity)**

Unloading Method	Vessel Type	Value	Material			
			Kerosene ^c	Water ^d	Motor Oil ^e	Surfactant Solution ^f
Pumping	Steel drum	Range	1.93 - 3.08	1.84 - 2.61	1.97 - 2.23	3.06
		Mean	2.48	2.29	2.06	3.06
Pumping	Plastic drum	Range	1.69 - 4.08	2.54 - 4.67	1.70 - 3.48	Not Available
		Mean	2.61	3.28	2.30	
Pouring	Bung-top steel drum	Range	0.244 - 0.472	0.266 - 0.458	0.677 - 0.787	0.485
		Mean	0.404	0.403	0.737	0.485
Pouring	Open-top steel drum	Range	0.032 - 0.080	0.026 - 0.039	0.328 - 0.368	0.089
		Mean	0.054	0.034	0.350	0.089
Gravity Drain	Slope-bottom steel tank	Range	0.020 - 0.039	0.016 - 0.024	0.100 - 0.121	0.048
		Mean	0.033	0.019	0.111	0.048
Gravity Drain	Dish-bottom steel tank	Range	0.031 - 0.042	0.033 - 0.034	0.133 - 0.191	0.058
		Mean	0.038	0.034	0.161	0.058
Gravity Drain	Dish-bottom glass-lined tank	Range	0.024 - 0.049	0.020 - 0.040	0.112 - 0.134	0.040
		Mean	0.040	0.033	0.127	0.040

^aFrom "Releases During Cleaning of Equipment." Prepared by PEI Associates, Inc., for the U.S. Environmental Protection Agency, Office of Pesticides and Toxic Substances, Washington DC, Contract No. 68-02-4248. June 30, 1986.

^bThe values listed in this table should only be applied to similar vessel types, unloading methods, and bulk fluid materials. At viscosities greater than 200 centipoise, the residue quantities can rise dramatically and the information on this table is not applicable.

^cFor kerosene, viscosity = 5 centipoise, surface tension = 29.3 dynes/cm²

^dFor water, viscosity = 4 centipoise, surface tension = 77.3 dynes/cm²

^eFor motor oil, viscosity = 97 centipoise, surface tension = 34.5 dynes/cm²

^fFor surfactant solution viscosity = 3 centipoise, surface tension = 31.4 dynes/cm²

The following example describes how the information in the table can be used to estimate the quantity of an EPCRA Section 313 chemical or chemical category in water that was used to clean drums on site.

Example - Container Residue

You have determined that a Form R for an EPCRA Section 313 chemical or chemical category must be submitted. The facility purchases and uses one thousand 55-gallon steel drums that contain a 10% aqueous solution of the chemical. Further, it is assumed that the physical properties of the solution are similar to water. The solution is pumped from the drums directly into a mixing vessel and the "empty" drums are triple-rinsed with water. The rinse water is indirectly discharged to a POTW and the cleaned drums are sent to a drum reclaimer.

From Table 4-1, the average drum residue quantity for this scenario is 2.29%. In this example, it can be assumed that all of the residual solution in the drums was transferred to the rinse water. Therefore, the quantity of the EPCRA Section 313 chemical transferred to the drum reclaimer should be reported as "zero."

The annual quantity of residual solution that is transferred to the rinse water can be estimated by multiplying the mean weight percent of residual solution remaining in a pumped steel drum by the total annual weight of solution in the drums. If the density is not known, it may be appropriate to use the density of water (8.34 pounds per gallon):

$$(0.0229\%) \times (55 \text{ gal/drum}) \times (1,000 \text{ drums}) \times (8.34 \text{ lb/gal}) \\ = 10,504 \text{ pounds solution}$$

The concentration of the EPCRA Section 313 chemical in the solution is only 10 percent.

$$(10,504 \text{ pounds solution}) \times (0.1\%) = 1,050 \text{ pounds EPCRA Section 313 chemical}$$

Therefore, 1,050 pounds of the EPCRA Section 313 chemical are transferred to the POTW and should be reported in Part II, Sections 6.1 and 8.7 of the 1998 Form R. Because they cannot be destroyed, metals cannot be reported as being treated, and metals and metal portions of metal compounds should be reported in Part II, Sections 6.1 and 8.1 of the 1998 Form R.

- h. On-Site Waste Treatment (Part II, Section 7A of Form R) - Includes all on-site waste treatment of EPCRA Section 313 chemicals or chemical categories. The information reported in Section 7A focuses on the treatment of the entire waste stream, not the specific EPCRA Section 313 chemical or chemical category. The information includes type of waste stream (gaseous, aqueous or non-aqueous liquid, or solid); treatment methods or sequence; influent concentrations of the EPCRA Section 313 chemical or chemical category; treatment efficiency (combined removal and destruction) of the entire method or sequence; and whether efficiency data is based on actual operating data. Metals and metal portions of metal compounds treated in a combustion process are not destroyed but should still be reported as going through the treatment process, with a treatment efficiency of zero. Note that only the metal portion of metal compounds should be reported in the Form R. The following example illustrates how Section 7A should be completed for on-site treatment of a wastewater**

stream containing three EPCRA Section 313 chemicals or chemical categories.

Example - On-Site Waste Treatment

A process at your facility generates a wastewater stream containing an EPCRA Section 313 chemical (chemical A). A second process generates a wastewater stream containing two EPCRA Section 313 chemicals, a metal (chemical B) and a mineral acid (chemical C). Thresholds for all three chemicals have been exceeded and you are in the process of completing separate Form Rs for each chemical.

Both wastewater streams are combined and sent to an on-site wastewater treatment system before being released to a POTW. This system consists of an oil/water separator that removes 99% of chemical A; a neutralization tank in which the pH is adjusted to 7.5, thereby destroying 100% of the mineral acid (chemical C); and a settling tank where 95% of the metal (chemical B) is removed from the water (and eventually land filled off site).

Section 7A should be completed slightly differently when you file the Form R for each of the chemicals or chemical categories. The table accompanying this example shows how Section 7A should be completed for each chemical or chemical category. First, on each Form R you should identify the type of waste stream in Section 7A.1a as wastewater (aqueous waste, code W). Next, on each Form R you should list the code for each of the treatment steps that is applied to the entire waste stream, regardless of whether the operation affects the chemical or chemical category for which you are completing the Form R (for instance, the first four blocks of Section 7A.1b of all three Form Rs should show: P19 (liquid phase separation), C11 (neutralization), P11 (settling/clarification), and N/A (to signify the end of the treatment system). Note that Section 7A.1b is the only section of the Form R that is not chemical or chemical category specific. It applies to the entire waste stream being treated. Section 7A.1c of each Form R should show the concentration of the specific chemical or chemical category in the influent to the first step of the process (oil/water separation). For this example, assume chemicals or chemical categories A, B, and C are all present at concentrations greater than 1 percent. Therefore, code "1" should be entered. Section 7A.1d is also chemical specific. It applies to the efficiency of the entire system in destroying and/or removing the chemical or chemical category for which you are preparing the Form R you are currently completing. You should enter 99% when filing for chemical A, 95% for chemical B, and 100% for chemical C. Finally, you should report whether the influent concentration and efficiency estimates are based on operating data for each chemical or chemical category, as appropriate.

Chemical A						
7A.1a	7A.1b	1. P19	2. C11	7A.1c	7A.1d	7A.1e
W	3. P11	4. N/A	5. _____	1	99 %	Yes No
	6. _____	7. _____	8. _____			X _____
Chemical B						
7A.1a	7A.1b	1. P19	2. C11	7A.1c	7A.1d	7A.1e
W	3. P11	4. N/A	5. _____	1	95 %	Yes No
	6. _____	7. _____	8. _____			X _____
Chemical C						
7A.1a	7A.1b	1. P19	2. C11	7A.1c	7A.1d	7A.1e
W	3. P11	4. N/A	5. _____	1	100 %	Yes No
	6. _____	7. _____	8. _____			X _____

Note that the quantity removed and/or destroyed is not reported in Section 7 and that the efficiency reported in Section 7A.1d refers to the amount of EPCRA Section 313 chemical or chemical category destroyed and/or removed from the applicable waste stream. The amount actually destroyed should be reported in Section 8.6 (quantity treated on site). For example, when completing the Form R for chemical B you should report "0" pounds in Section 8.6 because the metal has been removed from the wastewater stream, but not actually destroyed. The quantity of chemical B that is ultimately land filled off site should be reported in Section 6.2 and 8.1. However, when completing the Form R for chemical C you should report the entire quantity in Section 8.6 because raising the pH to 7.5 will completely destroy the mineral acid.

- i. **On-Site Energy Recovery (Part II, Section 7B of Form R)** - Includes all on-site energy recovery of reported EPCRA Section 313 chemicals and chemical categories. U.S. EPA's view is that EPCRA Section 313 chemicals or chemical categories that do not contribute significant heat energy during combustion processes should not be considered for energy recovery. Therefore, only EPCRA Section 313 chemicals or chemical categories with a significant heating value that are combusted in an energy recovery unit, such as an industrial furnace, kiln, or boiler can be reported for energy recovery. If an EPCRA Section 313 chemical or chemical category is incinerated on site but does not significantly contribute energy to the process (e.g., chlorofluorocarbons (CFCs)), it must be considered on-site waste treatment (see 4.1.3, h. above). Metals and metal portions of metal compounds will never be combusted for energy recovery. Note that only the metal portion of metal compounds should be reported in the Form R.
- j. **On-Site Recycling (Part II, Section 7C of Form R)** - Includes all on-site recycling methods used on EPCRA Section 313 chemicals or chemical categories.
- k. **Source Reduction and Recycling Activities (Part II, Section 8 of Form R)¹** - Provide information about source reduction and recycling activities related to the EPCRA Section 313 chemical or chemical category for which release and other waste management activities are being reported. Section 8 uses some data collected to complete Part II, Sections 5 through 7. For this reason, Section 8 should be completed last. The relationship between Sections 5, 6, and 8.8 to Sections 8.1, 8.3, 8.5, and 8.7 are provided in equation forms below.
 - (1) **Quantity Released (Part II, Section 8.1 of Form R)** - The quantity reported in Section 8.1 is the quantity reported in all of Section 5 plus the quantity of metals and metal compounds reported as discharged off site to POTWs in Section 6.1 plus the quantity reported as sent off site for disposal in Section 6.2 minus

¹The Subsection 8.1 through 8.8 designations are for the 1997 Form R. Please refer to the current reporting year *TRI Forms and Instructions* for any changes.

the quantity reported in Section 8.8 that was released on site or sent off site for disposal:

$$\S 8.1 = \S 5 + \S 6.1 \text{ (metals and metal compounds)} + \S 6.2 \text{ (disposal)} - \S 8.8 \text{ (on-site release or off-site disposal only)}$$

- (2) **Quantity Used for Energy Recovery On-Site (Part II, Section 8.2 of Form R)** - Estimate the quantity of the EPCRA Section 313 chemical or chemical category in wastes combusted for energy recovery on site. This estimate should be the quantity of the chemical or chemical category combusted in the process for which codes were reported in Section 7B. Test data from trial burns or other monitoring data may be used to estimate the quantity of the EPCRA Section 313 chemical or chemical category combusted for energy recovery purposes. If monitoring data are not available, vendor specifications regarding combustion efficiency may be used as they relate to the EPCRA Section 313 chemical or chemical category. A quantity must be reported in Section 8.2 when a method of on-site energy recovery is reported in Section 7B and vice versa.

Two conditions need to be met to report the combustion of an EPCRA Section 313 chemical or chemical category in waste as energy recovery: the chemical or chemical category (1) must have a significant heating value and (2) must be combusted in an energy recovery unit, such as a waste heat boiler, an industrial furnace, or a kiln. If an EPCRA Section 313 chemical or chemical category that does not have a significant heating value (except metals and metal compounds) is combusted for energy recovery on site, it must be considered on-site waste treatment (see 4.1.3.h). Metals and metal compounds in a waste that are combusted on site will never be combusted for energy recovery and are considered to be disposed. Note that "NA" should be reported for EPCRA Section 313 chemicals or chemical categories that do not have a significant heating value. This includes metals, metal portions of metal compounds, halogens, hydrochlorofluorocarbons (HCFCs), and CFCs.

- (3) **Quantity Used for Energy Recovery Off-Site (Part II, Section 8.3 of Form R)** - The quantity reported in Section 8.3 is the quantity reported in Section 6.2 for which energy recovery codes are reported. If a quantity is reported in Section 8.8, subtract any associated off-site transfers for energy recovery:

$$\S 8.3 = \S 6.2 \text{ (energy recovery)} - \S 8.8 \text{ (off-site energy recovery)}$$

Two conditions need to be met to report the combustion of an EPCRA Section 313 chemical or chemical category in waste as energy recovery: the chemical (1) must have a significant heating value and (2) must be combusted in an energy recovery unit, such as a waste heat boiler, an industrial furnace, or a kiln. If an EPCRA Section 313 chemical or chemical category that does not have a significant heating value (except metals and metal compounds) is sent off site for energy recovery, it must be considered off-site waste treatment (see 4.1.3.g). Metals and metal compounds sent off site for combustion in energy recovery units must be considered as sent off site for disposal because typically they will ultimately be disposed. Metals and metal portions of metal compounds will never be treated or combusted for energy recovery. Note that only the metal portion of metal compounds should be reported in the Form R. Also note that "NA" should be reported for EPCRA Section 313 chemicals or chemical categories that do not have a significant heating value. This includes metals, metal portions of metal compounds, halogens, HCFCs, and CFCs.

- (4) **Quantity Recycled On-Site (Part II, Section 8.4 of Form R) -** Estimate the quantity of the EPCRA Section 313 chemical or chemical category recycled in wastes on site. This estimate should be the quantity of the chemical or chemical category recycled in the process for which codes were reported in Section 7C. A quantity should be reported in Section 8.4 when a method of on-site recycling is reported in Section 7C and vice versa. To estimate this quantity, you should determine if operating data exist that indicate a recovery efficiency and use that efficiency value combined with throughput data to calculate an estimate. If operating data are unavailable, vendor specifications may be appropriate.
- (5) **Quantity Recycled Off-Site (Part II, Section 8.5 of Form R) -** The quantity reported in Section 8.5 must be the same as the quantity reported in Section 6.2 for which recycling codes are reported. If a quantity is reported in Section 8.8, subtract any associated off-site transfers for recycling:
- $$\S 8.5 = \S 6.2 \text{ (recycling)} - \S 8.8 \text{ (off-site recycling)}$$
- (6) **Quantity Treated On-Site (Part II, Section 8.6 of Form R) -** Waste treatment in Section 8 is limited to the destruction or chemical conversion of the EPCRA Section 313 chemical or chemical category in wastes. The quantities reported in Section 8.6 will be those that have undergone processes that are a subset of the processes for which codes were reported in Section 7A, where treatment includes physical removal from a waste stream. To

estimate the quantity treated, you should determine if operating data exist that indicate a treatment efficiency (e.g., destruction or chemical conversion of the EPCRA Section 313 chemical or chemical category) and use that efficiency value combined with throughput data to calculate an estimate. Because metals cannot be destroyed or chemically converted into something other than the metal or metal compound, metals cannot be reported as being treated in Section 8.6. Note that conversion of a metal from one oxidation state to another (e.g., Cr(VI) to Cr(III)) is not considered treatment for Section 8.6. If operating data are unavailable, available vendor specifications may be appropriate. Section 7A must be completed if a quantity is entered in Section 8.6.

- (7) **Quantity Treated Off-Site (Part II, Section 8.7 of Form R)** - The quantity reported in Section 8.7 must be the same as the quantity reported in Section 6.2 for which treatment codes are reported plus quantities sent to a POTW as reported in Section 6.1, except for metals and metal compounds. If a quantity is reported in Section 8.8, subtract any associated off-site transfers for treatment:

$$\begin{aligned} \text{\$8.7} &= \text{\$6.1 (except metals and metal compounds)} + \text{\$6.2} \\ &(\text{treatment}) - \text{\$8.8 (off-site treatment)} \end{aligned}$$

Because metals cannot be destroyed or chemically converted into something other than the metal or metal compound, metals cannot be reported as treated in Section 8.7. Quantities of metals reported in Section 6.1 and 6.2 should be reported in Section 8.1 (Quantity Released) unless the facility has knowledge that the metal is being recovered.

- (8) **Quantity Released to the Environment as a Result of Remedial Actions, Catastrophic Events, or One-Time Events Not Associated with Production Processes (Part II, Section 8.8 of Form R)** - The purpose of this section is to separate quantities recycled off site, used for energy recovery off site, treated off site, or released (including disposed) that are associated with normal or routine production from those quantities that are not. The quantity reported in Section 8.8 is the quantity of the EPCRA Section 313 chemical or chemical category released directly into the environment or sent off site for recycling, energy recovery, treatment, or disposal during the reporting year because of any of the following events:

- Remedial actions;
- Catastrophic events such as earthquakes, fires, or floods; or

- One-time events not associated with normal or routine production processes.

The quantity reported in Section 8.8 should not be included with quantities reported in Part II, Sections 8.1 through 8.7 of Form R, but should be included in Part II, Sections 5 and 6 of Form R as appropriate.

Spills that occur as a routine part of production operations and could be reduced or eliminated by improved handling, loading, or unloading procedures are included in the quantities reported in Section 8.1 through 8.7 as appropriate. This includes small drippings and spills that often occur during transfer operations and loading/unloading operations.

On-site releases and off-site transfers for further waste management from remediation of an EPCRA Section 313 chemical or chemical category or an unpreventable accident unrelated to production (such as a hurricane) are reportable in Section 8.8.

On-site treatment, energy recovery, or recycling of EPCRA Section 313 chemicals or chemical categories in wastes generated as a result of remedial actions, catastrophic events, or one-time events not associated with production processes are not reported in Part II, Section 8.8 nor Sections 8.1 through 8.7 of Form R.

COMMON ERROR - Double Counting

Release and other waste management activities should not be inadvertently "double counted." A single wastewater discharge should not be listed as both a release to water (on site) and a discharge to POTW (off site). Similarly, a release to land should not be listed as both a release to land (on site) and a transfer to an off-site landfill if the sludge from a surface impoundment is ultimately shipped off site. Estimates of release and other waste management activities should be prepared for Sections 5 through 7 of the Form R. For the most part, Section 8 relies on the data collected to complete these previous sections. Therefore, Section 8 should be completed last. However, the data elements of Section 8 (8.1 through 8.7) are mutually exclusive and care should be taken to avoid double counting.

4.1.4

Step 4: Determine the Most Appropriate Method(s) to Calculate the Estimates for Release and Other Waste Management Activity Quantities

After you have identified all of the potential sources for release and other waste management activity types, you must estimate the quantities of each EPCRA Section 313 chemical and chemical category released and otherwise managed as waste. U.S. EPA has

identified four basic methods that may be used to develop estimates (each estimate has been assigned a code that must be identified when reporting). The methods and corresponding codes are:

- Monitoring Data or Direct Measurement (M);
- Mass Balance (C);
- Emission Factors (E); and,
- Engineering Calculations (O).

Descriptions of these techniques are provided in the U.S. EPA publication, *Estimating Releases and Waste Treatment Efficiencies for the Toxic Chemical Release Inventory Forms* (1999 edition). They are also briefly described below. A more detailed discussion including examples of selected calculation techniques is presented in Appendix B. U.S. EPA does not require you to conduct additional sampling or testing for EPCRA Section 313 reporting; however, you are required to use the best readily available information to determine the method that will result in the most accurate estimate. For example, it may not be appropriate to use emission factors or engineering calculations if more accurate data, such as stack testing results, are available. You are required to identify the primary method used for each estimation.

Many potential sources of data exist for these (and other) methods of developing estimates. Table 4-2 presents potential data sources and the estimation methodology in which they are most likely to be used. Based on site-specific knowledge and potential data sources available, you should be able to determine the best method for calculating each release and other waste management activity quantity.

Once all potential release and other waste management activity sources, types, and estimation methods have been determined, an estimate for each EPCRA Section 313 chemical and chemical category can be developed corresponding to the elements on Form R.

Table 4-2

Potential Data Sources for Release and Other Waste Management Calculations

DATA SOURCES	
<u>Monitoring Data</u>	<u>Mass Balance</u>
<ul style="list-style-type: none"> • Air permits • Continuous emission monitoring • Effluent limitations • Hazardous waste analysis • Industrial hygiene monitoring data • New Source Performance Standards • NPDES permits • Outfall monitoring data • pH for acids and bases • POTW pretreatment standards • RCRA permit • Stack monitoring data 	<ul style="list-style-type: none"> • Air emissions inventory • Hazardous material inventory • Hazardous waste manifests • MSDSs • Pollution prevention reports • Spill event records • Supply records
<u>Emission Factors</u>	<u>Engineering Calculations</u>
<ul style="list-style-type: none"> • AP-42 chemical specific emission factors • Facility or trade association derived <u>chemical-specific</u> emission factors 	<ul style="list-style-type: none"> • Facility <u>non-chemical</u> specific emission factors. • Henry's Law • Raoult's Law • SOCM^I* or trade association non-chemical specific emission factors • Solubilities • Volatilization rates

* Synthetic Organic Chemicals Manufacturing Industry

4.1.4.1 Monitoring Data or Direct Measurement (code M)

Using monitoring data or direct measurements is usually the best method for developing chemical release and other waste management activity quantity estimates. Your facility may be required to perform monitoring under provisions of the Clean Air Act (CAA), Clean Water Act (CWA), RCRA, or other regulations. If so, data should be available for developing estimates. Data may have also been collected for your facility through an occupational health and safety assessment. If only a small amount of direct measurement data are available or if you believe the monitoring data are not representative, you must decide if another estimation method would give a more accurate result.

Example - Monitoring Data

Data from the on-site wastewater treatment facility indicate that the annual average concentration of copper in the discharge is 2 mg/L. The wastewater treatment facility processed 1.5 million gallons of water in 1997. The treated wastewater is discharged to an off-site POTW. The amount of copper transferred off site to the POTW (for Section 6.1 of the Form R) is estimated as follows:

Amount of copper transferred

$$\begin{aligned} &= (2 \text{ mg/L}) \times \left(\frac{\text{g}}{1,000 \text{ mg}} \right) \times \left(\frac{\text{lbs}}{453.59 \text{ g}} \right) \times \left(\frac{\text{L}}{0.2642 \text{ gal}} \right) \times (1,500,000 \text{ gal/yr}) \\ &= 25 \text{ lb/yr} \end{aligned}$$

COMMON ERROR - Treatment Efficiencies

Vendor data on treatment efficiencies often represent ideal operating conditions. You should adjust such data to account for downtime and process upsets during the year that would result in lower efficiencies. Remember that efficiencies reported by vendors are often general and may not apply to specific chemicals. For example, an incinerator or flare may be 99.99% efficient in destroying certain organic chemicals, but will have a 0% efficiency in destroying metals.

4.1.4.2 Mass Balance (code C)

A mass balance involves determining the amount of an EPCRA Section 313 chemical or chemical category entering and leaving an operation. The mass balance is written as follows:

$$\text{Input} + \text{Generation} = \text{Output} + \text{Consumption}$$

where:

- **Input** refers to the materials (chemicals) entering an operation. For example, chlorine added to process water as a disinfectant would be considered an input to the water treatment operation.
- **Generation** identifies those chemicals created during an operation (manufactured, including coincidental manufacturing). For example, when nitrogen sources are used in biological wastewater treatment systems, additional ammonia may be coincidentally manufactured.

- Output refers to the materials (chemicals) leaving an operation by various avenues. Output (avenues) may include on-site release and other on-site waste management activities; transfers off site for recycling, energy recovery, treatment, storage, or disposal; or the amount of chemical that leaves with the final product. For example, solvents used to clean wafers between different processes may leave the operation through air emissions or as liquid hazardous waste.
- Consumption refers to the amount of chemical converted to another substance during the operation (i.e., reacted). For example, nitric acid would be consumed by a neutralization during wastewater treatment.

The mass balance technique may be used for manufactured, processed, or otherwise used chemicals. It is typically most useful for otherwise used chemicals that do not become part of the final product, such as catalysts, solvents, acids, and bases. For large input and outputs, a mass balance may not be the best estimation method, because slight uncertainties in mass calculations can yield significant errors in the release and other waste management estimates.

Example - Mass Balance

A facility otherwise uses a volatile EPCRA Section 313 chemical as a refrigerant and adds 20,000 pounds to the refrigeration system (to make up for system losses). The chemical is released to the air from relief vents, during system filling operations and from leaks in valves and fittings. During system maintenance, the lines are bled directly into water and the system is vented to the air. Monitoring data of the wastewater, including chemical concentrations and wastewater throughput, indicate that 1,200 pounds of the chemical were discharged to the wastewater. The remaining losses are assumed to be fugitive air releases and are estimated as follows:

Fugitive air releases of the EPCRA Section 313 chemical:

$$\begin{aligned}
 &= \text{Amount input (lb/yr)} - \text{Amount released to wastewater (lb/yr)} \\
 &= 20,000 \text{ lb/yr} - 1,200 \text{ lb/yr} \\
 &= 18,800 \text{ lb/yr}
 \end{aligned}$$

COMMON ERROR - Mass Balances for Otherwise Used Chemicals

Facilities often do not account for the entire quantity of EPCRA Section 313 chemicals or chemical categories that are otherwise used. Many EPCRA Section 313 chemicals and chemical categories in the semiconductor manufacturing industry are classified as otherwise used. Such chemicals and chemical categories rarely leave the facility with the product. In these instances, all throughput may be lost during processing through on-site releases to air, water, or land, or it may be shipped off site for further waste management activities. Thus, the entire throughput is often reportable on Form R as release and other waste management activities to various media. Be sure to consider the entire throughput in these circumstances and partition it as appropriate. A mass balance may be the best starting point to estimate the release and other waste management quantities.

4.1.4.3 Emission Factors (code E)

An emission factor is a representative value that attempts to relate the quantity of a chemical or chemical category released with an associated activity. These factors are usually expressed as the weight of chemical or chemical category released divided by a unit weight, volume, distance, or duration of the activity releasing the chemical (e.g., pounds of chemical released per pounds of product produced). Emission factors, commonly used to estimate air emissions, have been developed for many different industries and activities. You should carefully evaluate the source of the emission factor and the conditions for its use to determine if it is applicable to the situation at your facility.

The most widely known and used source for emission factors is U.S. EPA's publication *Compilation of Air Pollutant Emission Factors (AP-42)*. Volume I of AP-42 contains information on over 200 stationary source categories, including process descriptions and potential sources of air emissions from these processes. Methodologies for estimating the quantity of air pollutant emissions from these sources are presented as Emission Factors. For EPCRA Section 313 purposes only CHEMICAL-SPECIFIC emission factors can be reported as Code "E" - Emission Factor in Part II, Section 5, Column B, Basis for estimate, of the Form R. AP-42 contains emission factors for individual chemicals and for the chemical group Volatile Organic Compounds (VOCs). The VOC emission factors are NOT chemical specific and when used must be reported in Column B as Code "O" - Engineering Calculations. Each chapter in Volume I covers a major industry or source category.

AP-42 can be accessed at the following Internet site:

- <http://www.epa.gov/ttn/chief/ap42.html>.

In an effort to provide current emissions data in an easy-to-access format, U.S. EPA has prepared a CD-ROM entitled Air CHIEF (Air ClearingHouse for Inventories and Emission Factors). The Air CHIEF CD-ROM is updated annually and is available from the Government Printing Office and can be ordered from their Web site. In addition to AP-42, the Air CHIEF CD-ROM contains the Factor Information Retrieval (FIRE) data system, a database management system containing U.S. EPA's recommended estimation factors for criteria and hazardous air pollutants. The CD-ROM also contains installable copies of software programs for air emission estimation models such as "TANKS" for VOC emission from storage tanks; "WATER8" for air emissions from wastewater systems; and "CHEMDAT8" for VOC emissions from Treatment, Storage, and Disposal Facility (TSDF) processes. Additional information on Air CHIEF and the CD-ROM is available at:

- <http://www.epa.gov/ttn/chief/airchief.html>.

Your facility may have developed emission factors for fugitive or stack emissions from process or control device exhaust vents based on stack tests for various air permits. Be sure to consider these emission factors if appropriate. However, if such factors are used, they are considered "engineering judgement" for the purposes of EPCRA Section 313 reporting.

Example - Emission Factors

Emission factors have been developed for air releases of fuel constituents and combustion products from boiler operations. AP-42 lists a range of formaldehyde emission factors when No. 6 fuel oil is consumed:

0.024 to 0.061 lb formaldehyde generated/10³ gal No. 6 fuel oil fired.

A facility operating a boiler using No. 6 fuel oil could use the above emission factor to determine the amount of formaldehyde generated and subsequently released to the air. If 1,000,000 gallons of No. 6 fuel oil is used during a reporting year, the amount of formaldehyde generated would be between:

$$(0.024 \text{ lb}/10^3 \text{ gal}) \times (1,000,000 \text{ gal}) \text{ and } (0.061 \text{ lb}/10^3 \text{ gal}) \times (1,000,000 \text{ gal})$$

$$= 24 \text{ and } 61 \text{ lb of formaldehyde}$$

NOTE: No. 6 fuel oil contains other EPCRA Section 313 chemicals and chemical categories and EPCRA Section 313 chemicals and chemical categories may also be coincidentally manufactured during combustion. All should be considered for EPCRA Section 313 reporting.

4.1.4.4 Engineering Calculations (code O)

Engineering calculations are assumptions and/or judgements used to estimate quantities of EPCRA Section 313 chemicals and chemical categories released or otherwise managed as waste. The quantities are estimated by using physical and chemical properties and relationships (e.g., Ideal Gas law, Raoult's law) or by modifying an emission factor to reflect the chemical properties of the chemical in question. Engineering calculations rely on the process parameters; you must have a thorough knowledge of your facility operations to complete these calculations.

Engineering calculations can also include computer models. Several computer models are available for estimating emissions from landfills, storage tanks, wastewater treatment, water treatment, and other processes.

Non-chemical-specific emission factors, Synthetic Organic Chemicals Manufacturing Industry (SOCMI) emission factors, industry-determined emission factors for processes or equipment, and site-specific emission factors also can be used, but must be classified as "engineering calculations" for EPCRA Section 313 reporting.

Example - Engineering Calculations

Stack monitoring data are available for xylene but you are required to report for toluene. Toluene is used in the same application as xylene at your facility and the concentrations of the chemicals in the liquid feedstock are approximately the same. Xylene and toluene are both used as wafer cleaning agents at a semiconductor manufacturing facility. You can estimate the emissions of toluene by adjusting the monitoring data of xylene by a ratio of the vapor pressure for xylene to toluene. This example is an engineering calculation based on physical properties and process operation information:

From facility stack monitoring data, an estimated 200 lb of xylene are released as air emissions during the reporting year. Toluene is also present in the air emissions, but not monitored. The stack operates at approximately 20°C. Based on literature data, the vapor pressures at 20°C for toluene is 22 millimeters of mercury (mmHg) and for xylene is 6 mmHg. Using a ratio of the vapor pressures, the amount of toluene released as air emissions from the stack can be calculated:

$$\begin{aligned} \frac{\text{X lb/yr toluene}}{200 \text{ lb/yr xylene}} &= \frac{22 \text{ mmHg (vapor pressure of toluene)}}{6 \text{ mmHg (vapor pressure of xylene)}} \\ \text{X lb/yr toluene} &= \frac{(200 \text{ lb/yr xylene}) \times (22 \text{ mmHg toluene})}{(6 \text{ mmHg xylene})} \end{aligned}$$

Completing the calculation, the facility determines that 730 lb of toluene were released as stack air emissions during the reporting year.

4.1.4.5 Estimating Release and Other Waste Management Quantities

Once all sources, types, and appropriate estimation methodologies have been identified, you can estimate the release and other waste management activity quantities for each element of the Form R. The recommended approach is that you estimate amounts from all sources at your facility to each type as identified by the elements of Form R. Table 4-3 presents a work sheet that may be helpful in compiling this information.

If you prepare a Form R, you must also enter on-site treatment information in Section 7A, including the code for each treatment method used, the destruction and removal efficiency for the EPCRA Section 313 chemical or chemical category in the treated waste stream, and the concentration of the EPCRA Section 313 chemical or chemical category in the influent to treatment. You should report treatment methods that do not actually destroy or remove the chemical or chemical category by entering "zero (0)" for removal efficiency. Similarly, on-site energy recovery methods and on-site recycling methods must be reported in Sections 7B and 7C, respectively.

Table 4-3

**Release and Other
Waste Management Quantity Estimation Worksheet**

Facility Name: _____
 EPCRA Section 313 Chemical or Chemical Category: _____
 CAS Registry Number: _____
 Reporting Year: _____

Date Worksheet Prepared: _____
 Prepared by: _____

ON SITE			
Release or Other Waste Management Activity Type	Amount (lb)	Basis of Estimate	Form R Element* (1998 version)
FUGITIVE AIR			
Equipment Leaks			5.1 and 8.1 or 8.8
Process Areas			5.1 and 8.1 or 8.8
Evaporative Losses, Spills, Surface Impoundments			5.1 and 8.1 or 8.8
Total =			5.1 and 8.1 or 8.8
STACK AIR			
Process Vents			5.2 and 8.1 or 8.8
Storage Tanks			5.2 and 8.1 or 8.8
Control Device Stacks			5.2 and 8.1 or 8.8
Other			5.2 and 8.1 or 8.8
Total =			5.2 and 8.1 or 8.8
RECEIVING STREAM/WATER BODY DISCHARGE			
Stormwater Discharge			5.3 and 8.1 or 8.8
On-Site Treatment Plant Discharge			5.3 and 8.1 or 8.8
Total =			5.3 and 8.1 or 8.8
ON-SITE UNDERGROUND INJECTION			
Underground Injection to Class I Wells			5.4 and 8.1 or 8.8
Underground Injection to Class II - V Wells			5.4 and 8.1 or 8.8
Total =			5.4 and 8.1 or 8.8

*Entries for Section 8.8 only if release is result of remedial action, catastrophic event, or one-time event not associated with production process.

Table 4-3 (Continued)

ON SITE			
Release or Other Waste Management Activity Type	Amount (lb)	Basis of Estimate	Form R Element* (1998 version)
ON-SITE LAND			
RCRA Subtitle C Landfill			5.5 and 8.1 or 8.8
Other Landfill			5.5 and 8.1 or 8.8
Land Treatment/Application Farming			5.5 and 8.1, or 8.8
Surface Impoundment			5.5 and 8.1 or 8.8
Other Disposal			5.5 and 8.1 or 8.8
Total =			5.5 and 8.1 or 8.8
ON-SITE ENERGY RECOVERY			
Industrial Kiln			8.2
Industrial Furnace			8.2
Industrial Boiler			8.2
Other Energy Recovery Methods			8.2
Total =			8.2
ON-SITE RECYCLING			
Solvents/Organics Recovery			8.4
Metals Recovery			8.4
Acid Regeneration			8.4
Other Reuse or Recovery			8.4
Total =			8.4
ON-SITE TREATMENT			
Air Emissions Treatment			8.6
Biological Treatment			8.6
Chemical Treatment			8.6
Incineration/Thermal Treatment			8.6
Physical Treatment			8.6
Solidification/Stabilization			8.6
Total =			8.6

*Entries for Section 8.8 only if release is result of remedial action, catastrophic event, or one-time event not associated with production process.

Table 4-3 (Continued)

OFF SITE				
Release or Other Waste Management Activity Type	Amount (lb)	Basis of Estimate	Form R Element* (1998 version)	Off-Site Location (name)
OFF-SITE DISPOSAL				
Solidification/Stabilization (metals and metal compounds only)			6.2 and 8.1 or 8.8	
Amount of metal and metal compounds to POTW			6.1 and 8.1 or 8.8	
Wastewater Treatment (excluding POTWs) metals and metal compounds only			6.2 and 8.1 or 8.8	
Underground Injection			6.2 and 8.1 or 8.8	
Landfill/Surface Impoundment			6.2 and 8.1 or 8.8	
Land Treatment			6.2 and 8.1 or 8.8	
Other Land Disposal			6.2 and 8.1 or 8.8	
Other Off-Site Management			6.2 and 8.1 or 8.8	
Total =			6.2 and 8.1 or 8.8	
OTHER AMOUNTS SENT OFF SITE				
Amounts sent for storage			6.2 and 8.1 or 8.8	
Amounts sent for unknown waste management practice			6.2 and 8.1 or 8.8	
Total =			6.2 and 8.1 or 8.8	
OFF-SITE TREATMENT				
Solidification/Stabilization			6.2 and 8.7 or 8.8	
Incineration/Thermal Treatment			6.2 and 8.7 or 8.8	
Incineration/Insignificant Fuel Value			6.2 and 8.7 or 8.8	
Wastewater Treatment (to POTW excluding metals and metal compounds)			6.1 and 8.7 or 8.8	
Wastewater Treatment (excluding POTW and metal and metal compounds)			6.2 and 8.7 or 8.8	
Sent to Waste Treatment Broker			6.2 and 8.7 or 8.8	
Total =			6.2 and 8.7 or 8.8	

*Entries for Section 8.8 only if release is result of remedial action, catastrophic event, or one-time event not associated with production process.

Table 4-3 (Continued)

OFF SITE				
Release or Other Waste Management Activity Type	Amount (lb)	Basis of Estimate	Form R Element* (1998 version)	Off-Site Location (name)
OFF-SITE ENERGY RECOVERY				
Off-Site Energy Recovery			6.2 and 8.3 or 8.8	
Sent to Energy Recovery Broker			6.2 and 8.3 or 8.8	
Total =			6.2 and 8.3 or 8.8	
OFF-SITE RECYCLING				
Solvents/Organics Recovery			6.2 and 8.5 or 8.8	
Metals Recovery			6.2 and 8.5 or 8.8	
Other Reuse or Recovery			6.2 and 8.5 or 8.8	
Acid Regeneration			6.2 and 8.5 or 8.8	
Sent to Recycling Waste Broker			6.2 and 8.5 or 8.8	
Total =			6.2 and 8.5 or 8.8	

*Entries for Section 8.8 only if release is result of remedial action, catastrophic event, or one-time event not associated with production process.

A semiconductor is a material that has an electrical conductivity between that of a conductor and an insulator; its electrical characteristics can be manipulated to behave like either depending on how it is processed. Silicon has traditionally been the substrate used to manufacture semiconductors; recently other materials such as gallium arsenide (GaAs) and indium phosphide (InP) have been used as a substrate material.

The semiconductor manufacturing process is continually evolving. The variety of distinct processing steps involved results in a range of processes that may occur at a single plant. Process designs are not uniform from plant to plant. An average semiconductor manufacturing process consists of hundreds of process steps, of which a significant percentage may be potential sources of EPCRA Section 313 chemicals. Many of the manufacturing steps are repeated several times during the production process. For these reasons, this document will discuss general manufacturing steps and does not attempt to describe a specific type of plant.

A clean environment is essential to the manufacture of semiconductors; thus cleaning operations precede and follow many of the manufacturing process steps. Wet processing, during which semiconductor devices are repeatedly immersed in or sprayed with solutions is commonly used to minimize the risk of contamination. Wet processes are the primary source of EPCRA Section 313 chemicals found in semiconductor manufacturing.

The primary component of a semiconductor is the semiconductor wafer, or chip. The manufacture of a semiconductor chip involves six basic processes (see Figure 4-3):

1. Photolithography
2. Thin Films
3. Etching
4. Cleaning
5. Doping
6. Chemical Mechanical Planarization

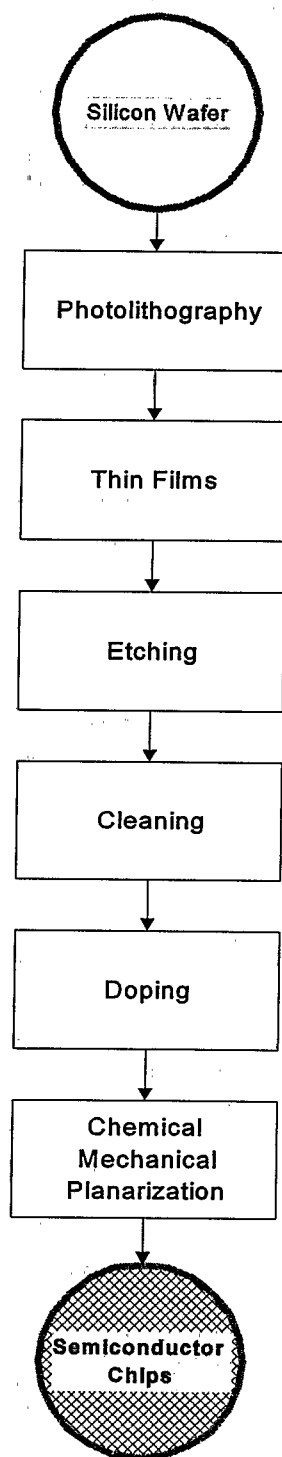


Figure 4-3. Overall Process Flow Diagram - Semiconductor Manufacturing

A single wafer may undergo one or more of these operations multiple times before processing is complete.

Through the use of these physical and chemical processes, hundreds of thousands of miniature transistors are created on the wafer. The result is the formation of integrated circuits on silicon wafers that, when cut into single "chips," can be packaged and marketed as separate electronic components to be used in various applications.

The following sections discuss each of the processing steps identified above and describe how to estimate release and other waste management activity quantities for each. It should be noted that many of the chemicals used in semiconductor manufacturing are used in more than one process, and some of the chemicals are used as a raw material as well as coincidentally manufactured through the use of other chemicals. For example, hydrochloric acid aerosols are used in wet etching processes and are also coincidentally manufactured in small quantities during dry etching, where free chlorine from chlorinated organics may react with a hydrogen carrier to produce hydrochloric acid aerosols. Also, regardless of which process a chemical is used in, acid/base streams are commonly treated in an on-site wastewater treatment plant and waste solvents are typically collected and sent off site for further waste management activities (such as recycling or energy recovery).

4.2.1 Photolithography

Photolithography is used in semiconductor manufacturing to form surface patterns on the wafer. These patterns will in turn allow various materials to be deposited on or removed from selected, precise locations. In this process a viscous, solvent-based, light-sensitive photoresist is applied to the wafer on a spin track. On the spin track a fixed amount of photoresist is metered onto the wafer, which is then spun at high speed on a rotating element to coat the wafer surface uniformly.

After a "soft bake" to remove most of the carrier solvent, a pattern is introduced into the resist by exposing predefined areas of the wafer to light, lasers, electron beams, or by other means. A template mask, which is a glass plate containing an image of the desired circuit may be used to introduce the pattern. Depending on the photoresist system, a developer solution is applied to dissolve some of the photoresist, yielding a stencil for further processing. Materials

may be added or removed from the unmasked areas, giving a printed circuit. The number of photolithography steps required depends on the type of integrated circuit.

After the subsequent processing steps, residual photoresist is removed by using wet stripping (solvent or acid) or plasma gas stripping.

As is the case with most of the EPCRA Section 313 chemicals used in the semiconductor manufacturing industry, photoresist solvents, strippers, and developers should be considered as otherwise used and are subject to the 10,000 pound per year reporting threshold.

COMMON ERROR - Solvent Reporting

Spin tracks used to apply photoresist may use automatic cleaning where solvent, typically isopropyl alcohol, acetone, or propylene glycol methyl ether acetate (PGMEA, CAS 108-65-6), is dispensed onto the spin track to prevent photoresist buildup. In this instance none of these chemicals would be reportable under EPCRA Section 313 reporting guidelines. Isopropyl alcohol is reportable only if it is manufactured by the strong acid process, acetone is not an EPCRA Section 313 chemical, and PGMEA does not fall into the "Certain Glycol Ethers" category.

4.2.1.1 Step 1: Prepare Process Flow Diagram

A site-specific process flow diagram should be prepared to help identify all potential sources and types of chemical releases and waste management activities. A typical flow diagram is presented in Figure 4-4. Please note that aqueous wastes and container residue should be reported as off-site transfer (disposal, recycling, treatment, energy recovery) as appropriate.

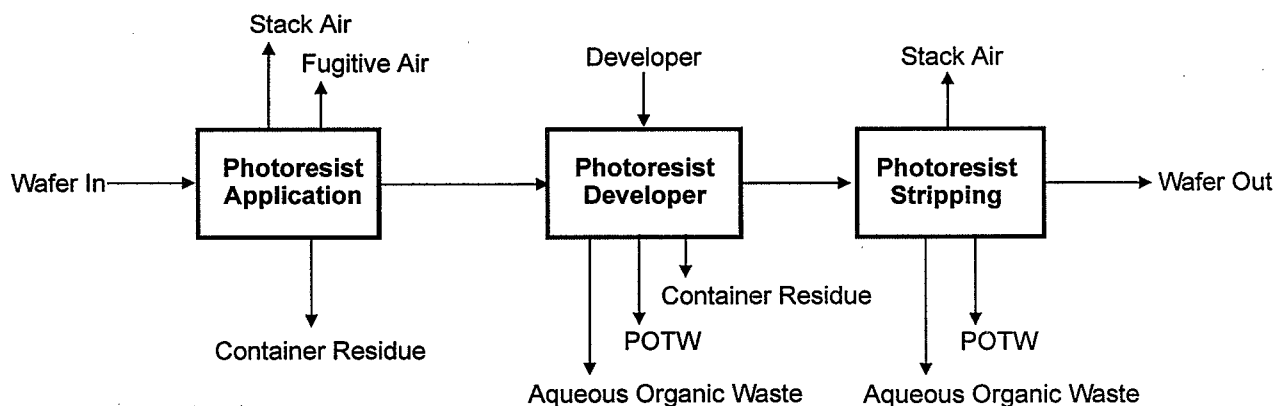


Figure 4-4. Process Flow Diagram for Typical Photolithography Process

4.2.1.2 Step 2: Identify Potential Sources of Chemical Release and Other Waste Management Activities

The most common potential sources of EPCRA Section 313 chemicals from photolithography are photoresist solvents, strippers, and developers. The primary release source is tool exhaust from the photoresist applicators, developing, and stripping stations; spent solvent, developer, and stripping solutions collected and sent either to a POTW or an off-site treatment, disposal, or energy recovery facility; and container residue. Typical EPCRA Section 313 chemicals include N-methyl-2-pyrrolidone, xylenes, glycol ethers, methanol, hydrofluoric acid, sulfuric acid aerosols, hydrochloric acid aerosols, ethylbenzene, and methyl ethyl ketone.

4.2.1.3 Step 3: Identify Release and Other Waste Management Activity Types

Release and other waste management activity types include fugitive and point source emissions to the air from wet chemical and solvent stations and control equipment exhaust, and off-site transfers to POTWs and treatment facilities. Vapors from organic solvents found in the photoresist and organic based (negative) photoresist strippers are typically sent to an on-site treatment unit, usually some type of concentrator (such as a carbon adsorber) followed by thermal destruction. Typical release and other waste management activity types and typical EPCRA Section 313 chemicals are:

Type of Release and Other Waste Management Activity	Typical EPCRA Section 313 Chemical
Stack Air	N-methyl-2-pyrrolidone, xylene, glycol ethers, ethylbenzene, methanol, hydrofluoric acid, sulfuric acid aerosols, hydrochloric acid aerosols, MEK
Fugitive Air	N-methyl-2-pyrrolidone, xylene, glycol ethers, ethylbenzene, methanol, hydrofluoric acid, sulfuric acid aerosols, hydrochloric acid aerosols, MEK
Off-Site Transfer From Container Residue (off-site recycle, energy recovery, treatment, or disposal)	N-methyl-2-pyrrolidone, xylene, glycol ethers, ethylbenzene, methanol, hydrofluoric acid, MEK
POTW	Glycol ethers, N-methyl-2-pyrrolidone, ethylbenzene, methanol, hydrofluoric acid, MEK
Off-Site Transfer	N-methyl-2-pyrrolidone, Xylene, glycol ethers, ethylbenzene, methanol, hydrofluoric acid, MEK
On-Site Treatment	N-methyl-2-pyrrolidone, xylene, glycol ethers, ethylbenzene, methanol, hydrofluoric acid, MEK

4.2.1.4

Step 4: Determine the Most Appropriate Method(s) to Calculate the Estimates for Release and Other Waste Management Activity Quantities

A mass balance approach is usually the most accurate method for determining release and other waste management activity quantities of EPCRA Section 313 chemicals typically found in photoresist, developers, and strippers. To completely account for all the different fates of the chemical in the mass balance equation, other information may be needed, such as concentration of the chemical in liquid wastes sent off site for further waste management activities.

Wastewater volumes are normally metered or may be estimated based on make-up quantities required. Wastewater concentrations of EPCRA Section 313 chemicals may already be monitored in compliance with discharge or pretreatment permit requirements. Flow and concentration data can be used to determine the amount of the EPCRA Section 313 chemical managed in this fashion.

Quantities of EPCRA Section 313 chemicals in "empty" container residues subject to waste management can be estimated using established residue factors based on the

method of cleaning or draining of the container (see Table 4-1 and the corresponding container residue example).

Example - Photolithography

Over the course of a year, a facility uses 17,000 pounds of glycol ethers as a photoresist solvent. Fumes from the process are vented to a thermal oxidizer that has been measured as being 95% efficient in removing solvent emissions from the exhaust stream. You must determine whether a reporting threshold is exceeded and if so, estimate the quantities released to the air, the POTW and sent for off site treatment.

Calculation Steps

1. Determine whether the glycol ethers that the facility uses fit the EPCRA 313 "Certain Glycol Ethers" category.

After comparing the CAS numbers of the glycol ethers used at the facility, you have determined that 11,000 pounds of the total glycol ethers used are included in the EPCRA 313 "Certain Glycol Ethers" category.

The use of glycol ethers is not an incorporative activity so all 11,000 pounds fall into the "otherwise use" threshold. Since the facility exceeded the "otherwise use" threshold of 10,000 pounds, all releases and other waste management quantities (except those specifically exempted) of "Certain Glycol Ethers" must be reported on the Form R.

2. Estimate releases to air, amount treated on-site, amount transferred off-site, and amount transferred to the POTW.

The facility has testing data to show that approximately 20% of the glycol ethers used evaporate from the process and are entrained in the airstream hoods going into the thermal oxidizer. Based on hazardous waste monitoring data, it is known that 75% of the glycol ethers used are drained from the process lines into a waste solvent tank. Waste from the solvent tank is transferred to an off site treatment site. The remaining 5% is sent to a POTW.

Stack Air Releases = $11,000 \times 0.2$ (portion which evaporates) $\times 0.05$ (to account for the control efficiency) = 110 (lb/year)

This value should be reported in Section 5.2 of the Form R and included in the estimate for Section 8.1.

Amount treated on-site = $11,000 \times 0.2 \times 0.95 = 2,090$ (lb/year)

This value should be reported in Section 8.6 of the Form R and the appropriate control information entered in Section 7A.

Off-site Transfer = $11,000 \times 0.75 = 8250$ pounds

This value should be reported in Section 6.2 of the Form R and included in the estimate for Section 8.7.

POTW releases = $11,000 \times 0.05 = 550$ pounds

This value should be reported in Section 6.1 of the Form R and included in the estimate for Section 8.7.

4.2.2

Thin Films

In thin film deposition, layers of single crystal silicon, polysilicon, silicon nitride, silicon dioxide, and other materials are deposited on the wafer to provide desirable properties on portions of the device or to serve as masks. Each of these films serves a specific purpose in device operation:

- Single crystal silicon films (also called epitaxial silicon) serve as the substrate in which the heart of transistors are constructed.
- Amorphous silicon films (also called polysilicon) serve as gate electrodes in most modern devices. These films are typically heavily doped to make them very conductive.
- Silicon nitride films serve as passivation layers that are used primarily as protective layers after most device processing has occurred; they may also be used as an etch stop in some cases.
- Silicon dioxide films are deposited by using silicon and oxygen precursor compounds or are oxidized using wet or dry oxidation processes, and are by far the most frequently deposited films. Silicon dioxide films act primarily as dielectric layers, but may also act as masks for subsequent processing.

Deposition of these films is frequently performed in a chemical vapor deposition (CVD) reactor or a high-temperature tube furnace using silicon-containing gases as reactants. The deposition rate can be further enhanced by striking a plasma to overcome kinetic barriers. Selected impurity compounds or dopants may be used in the deposition process to alter the electrical characteristics of the deposited film or layer. Sometimes a chlorine source (chlorine gas, hydrogen chloride gas, or 1,2-dichloroethylene) is used during oxidation to modify the oxide characteristics.

Typical EPCRA Section 313 chemicals used in these deposition processes are chlorine, anhydrous ammonia (gas) and 1,2-dichloroethylene.

To interconnect electrical devices on an integrated circuit and to provide for external connections, metallic layers are deposited onto the wafer by evaporation, sputtering, or CVD. Evaporation consists of vaporizing a metal under a vacuum at a very high temperature.

Sputtering processes (also called physical vapor deposition or PVD) involve bombarding metallic targets with a plasma gas, which displaces ions from the target and deposits them on the wafer. CVD of metal is similar to the other deposition processes described above except that the reactive gas is a metal-containing vapor. Devices may have a single layer or multiple layers of metal.

Typical EPCRA Section 313 chemicals used in metallization processes are arsenic, arsine, boron, trifluoride, diborane, ammonia and compounds of aluminum and copper.

Thin films application is one process used in semiconductor manufacturing in which EPCRA Section 313 chemicals are actually introduced and intentionally incorporated into the final product. Therefore they are considered to be processed and are subject to the 25,000 pound per year reporting threshold.

4.2.2.1 Step 1: Prepare Process Flow Diagram

A site-specific process flow diagram should be prepared to help identify all potential sources and types of chemical releases and waste management activities. A typical flow diagram is presented in Figure 4-5.

4.2.2.2 Step 2: Identify Potential Sources of Chemical Release and Other Waste Management Activities

Potential sources of EPCRA Section 313 chemicals from application of thin films include: ammonia gas used as a nitrogen source in silicon nitride deposition, organics used as chlorine sources, organics used to clean deposition furnaces, and metals deposited to interconnect electrical devices. The primary point of release and other waste management quantities is the thin film deposition tool (furnace or oxidation chamber). Exhaust from these tools is typically routed to a scrubber which vents to the atmosphere and also result in wastewater generation.

4.2.2.3

Step 3: Identify Release and Other Waste Management Activity Types

Common release and other waste management activity types from thin film deposition processes include point source air, on-site treatment, and off-site disposal. Typical release and other waste management activity types and typical EPCRA Section 313 chemicals are:

Type of Release and Other Waste Management Activity	Typical EPCRA Section 313 Chemical
Stack Air	Ammonia, 1,2-dichloroethylene
Fugitive Air	Ammonia, 1,2-dichloroethylene
POTW	Ammonia
Solid Waste Disposal	Copper
On-Site Treatment	1,2-dichloroethylene

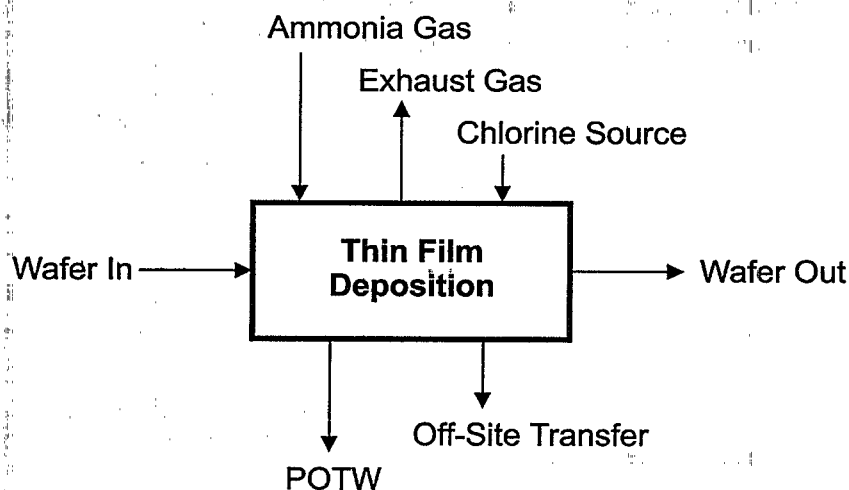


Figure 4-5. Process Flow Diagram for Typical Thin Film Process

4.2.2.4

Step 4: Determine the Most Appropriate Method(s) to Calculate the Estimates for Release and Other Waste Management Activity Quantities

Release and other waste management quantities of EPCRA Section 313 chemicals used as chlorine sources (and also used as a cleaner for furnace interiors) may be calculated using a mass balance approach or engineering calculations. Determining the amount of ammonia releases to the air usually requires some type of stack testing information used in conjunction with purchase records and effluent monitoring data. It should be noted that ammonia gas is anhydrous ammonia and 100% of the ammonia used in this form should be considered in both threshold determinations and release calculations. Release and other waste management quantities of metal-containing solid waste may be estimated using waste profiles (if available) or purchase records.

Example - Thin Films

In addition to ammonia used in etching and cleaning, anhydrous ammonia is also used at the facility in thin film deposition to deposit a layer of silicon nitride during wafer fabrication. Over the course of a year, 17,000 pounds of ammonia is used in this process. Since ammonia is used in this application in an incorporative activity (although not all of the nitrogen in the ammonia is actually incorporated), it is considered toward the processing threshold of 25,000 pounds which is not exceeded for this application. However, as described above, ammonia is also used as a cleaner and the threshold is exceeded for that activity. Therefore, you must also account for the release and other waste management activities of ammonia from thin film deposition.

It is known that 20 percent of the total ammonia used ends up being deposited on the wafer, with the remainder being vented to an on-site treatment system (scrubber) with a control efficiency of 90 percent.

Point source air emissions are then calculated as follows:

Point Source Air Emissions = 17,000 (lb/year) x 0.8 (amount not deposited on the wafer) x (1 - control efficiency)

$$= 17,000 \text{ (lb/year)} \times 0.8 \times (1 - 0.9)$$

$$= 1,360 \text{ (lb/year)}$$

This value should be reported in Section 5.2 of the Form R and included in the estimate for Section 8.1.

The amount sent to the POTW (effluent from the scrubber) is calculated as follows:

Release to POTW = 17,000 (lb/year) x 0.8 (amount not deposited on the wafer) x (control efficiency) x 10 percent (adjustment for aqueous ammonia)

$$= 17,000 \text{ (lb/year)} \times 0.8 \times 0.9 \times 0.1$$

$$= 1,224 \text{ (lb/year)}$$

This value should be reported in Section 6.1 of the Form R and included in the estimate for Section 8.7.

It should be noted that the amount sent to the POTW was adjusted to 10% of the total based on the reporting requirements for aqueous ammonia.

4.2.3

Etching

Etching is used to chemically remove specific unwanted areas of silicon substrate or deposited film so that an underlying material may be exposed, or another material may be deposited, in the etched material's place. Etching processes usually occur after a photoresist pattern has been applied, so that the etching is accomplished in specific areas.

Etching may be performed using either solutions of acids, bases, or oxidizers (wet etching), or by using various gases (usually halogenated) in a plasma environment (dry etching). In dry etching, halogenated gases are excited in a plasma so that they split apart forming reactive halogen radicals. The halogen radical etches the surface of the wafer. Typical examples of chemicals used in dry etching are chlorine and 1,1-dichloro-1-fluoroethane.

Dry etching provides a higher resolution than wet etching, generally produces less undercutting of the wafer substrate, and is more likely to be used as circuit elements become smaller. In either case, the fluoride ion or radical is almost always introduced if the substrate or film to be etched contains silicon oxide or silicon nitride. Chloride species are used if only silicon is to be etched.

Typical examples of chemicals used in wet etching processes include chlorine, ethylene glycol, hydrochloric acid aerosols, hydrogen fluoride, nitric acid, phosphoric acid, and sulfuric acid aerosols.

COMMON ERROR - Acid Aerosol Reporting

Both hydrochloric acid and sulfuric acid have qualifiers stating that only aerosol forms of the chemicals are subject to the EPCRA Section 313 reporting requirements. Etching and cleaning processes that spray hydrochloric and sulfuric acid create what EPCRA Section 313 defines to be "aerosol" forms of these acids. In this case, acid aerosols are both manufactured (subject to the 25,000 pound per year reporting threshold) as well as otherwise used (subject to the 10,000 pound per year reporting threshold). If you otherwise use these chemicals or manufacture them in etching or cleaning processes and exceed either threshold, you must prepare an EPCRA Section 313 report. See Appendix C for further guidance on this issue.

COMMON ERROR - Nitric Acid and Nitrate Compound Reporting

Do not overlook the coincidental manufacture of nitrate compounds from on-site wastewater treatment of nitric acid. In the etching process, nitric acid is typically collected and sent to an on-site treatment plant, where it is neutralized and discharged to a POTW. Nitrate compounds are coincidentally manufactured during the neutralization of nitric acid and are subject to the 25,000 pounds per year manufacturing threshold. If the threshold is exceeded, corresponding releases should be reported as a "Discharge to POTW" in Section 6.1 (and also in Section 8.1) of the Form R, and not reported under Section 6.2 "Transfers to Other Off-Site Locations." Further information on nitric acid neutralization and associated nitrate compound generation may be found in Appendix D - List of Toxic Chemicals Within the Water Dissociable Nitrate Compounds Category and Guidance for Reporting.

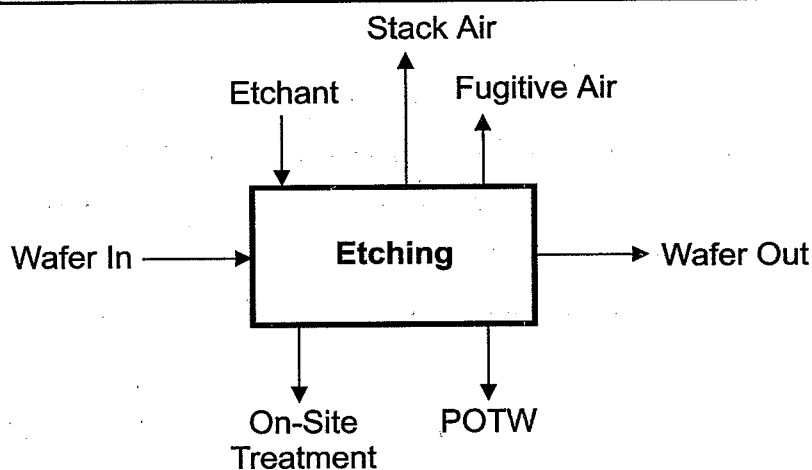


Figure 4-6. Process Flow Diagram for Typical Etching Process

4.2.3.1 Step 1: Prepare Process Flow Diagram

A site-specific process flow diagram should be prepared to help identify all potential sources and types of chemical releases and waste management activities. A typical flow diagram is presented in Figure 4-6.

4.2.3.2 Step 2: Identify Potential Sources of Chemical Release and Other Waste Management Activities

The most common potential source of EPCRA Section 313 chemicals from etching is the etchant material itself, usually inorganic acids used in wet etching processes, and

certain halogenated organic compounds used in dry etching processes. Acid vapors from the etching tools are usually vented through a scrubber. In turn, spent scrubber water is usually routed to an on-site treatment plant for neutralization prior to discharge to a receiving stream or POTW.

4.2.3.3 Step 3: Identify Release and Other Waste Management Activity Types

Release and other waste management activity types include stack air, container residue, fugitive air, and discharge to a POTW. Most acids used in etching processes should be reported in Section 7A and 8.6 for on-site treatment (see "On-Site Waste Treatment" example in Section 4.1.3). Acids do not need to be reported as off-site transfers or releases if the effluent from the on-site treatment plant has a pH between 6 and 9. They are considered to be completely neutralized if they are within this pH range. However, release must be accounted for any time the effluent pH drops below 6. Also, the neutralization of nitric acid used in etching processes will result in the coincidental manufacture of nitrate compounds, which in turn are sent to a POTW.

Typical release and other waste management activity types and typical EPCRA Section 313 chemicals used in etching processes are:

Type of Release and Other Waste Management Activity	Typical EPCRA Section 313 Chemical
Stack Air	Hydrochloric acid aerosols, sulfuric acid aerosols, nitric acid
Fugitive Air	Hydrochloric acid aerosols, sulfuric acid aerosols, nitric acid
POTW	Nitrate compounds
On-site Treatment	Hydrochloric acid aerosols, sulfuric acid aerosols, nitric acid

4.2.3.4 Step 4: Determine the Most Appropriate Method(s) to Calculate the Estimates for Release and Other Waste Management Activity Quantities

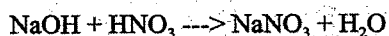
Most of the inorganic acids used in etching processes will end up in the on-site wastewater treatment plant and should be reported as "treated on site" if the effluent from the plant has a pH between 6 and 9. Smaller amounts will be released from the acid scrubber stacks;

stack test results are the best way to determine these quantities. Further information on estimating releases of mineral acids can be found in the document "Estimating Releases for Mineral Acid Discharges Using pH Measurements, U.S. Environmental Protection Agency, June 1991."

Example - Etching

Your facility uses 100,000 pounds per year of nitric acid as an etchant. It is sent to an on-site wastewater treatment plant for neutralization prior to discharge to the local POTW. Nitrate compounds are formed as part of the neutralization process. You are attempting to estimate the releases of nitrate compounds to the POTW. For this example, assume all nitric acid is converted to nitrates during treatment and that the pH of the treatment plant effluent never drops below 6.

The neutralization reaction occurring at the wastewater treatment plant is:



Since the pH never drops below 6, the amount of nitric acid treated on site would equal 100,000 pounds.

$$\begin{aligned} \text{Pounds of nitrates produced} &= (\text{Pounds of nitric acid sent to treatment}) \times \\ &\quad (1 \text{ mol NO}_3 / 1 \text{ mol HNO}_3) \times \\ &\quad (1 \text{ mol HNO}_3 / 63 \text{ lb}) \times (62 \text{ lb} / \text{mol NO}_3) \\ &= (100,000 \text{ lb HNO}_3) \times (1 \text{ mol NO}_3 / \text{mol} \\ &\quad \text{HNO}_3) \times (1 \text{ mol HNO}_3 / 63 \text{ lb}) \times \\ &\quad (62 \text{ lb NO}_3 / \text{mol}) \\ &= 98,413 \text{ pounds of Nitrate produced at treatment and sent to the POTW} \end{aligned}$$

It should be noted that metal compounds (such as metal nitrates) may be formed during etching processes and need to be considered in all threshold and release and other waste management activity quantities.

4.2.4 Cleaning

Wafer cleaning is required to prepare them for each chemical and physical process to ensure that contaminants on the wafer surfaces do not affect the final integrated circuit's electrical performance. Before, and sometimes after, wafers are subjected to any specialized manufacturing processes, they are typically immersed in, or sprayed with, various aqueous and/or organic solutions. In some cases they are mechanically scrubbed to remove films, residues, bacteria, or other particles. Fog chambers may also be used for wafer cleaning.

In addition to cleaning of the actual wafer, equipment is also cleaned using inorganic acids and organic solvents. As discussed in Section 4.2.3, hydrochloric and sulfuric

acids are only reportable if used in aerosol form. If these acids are used in wet benches or baths (such as dip tanks), then they are not reportable.

4.2.4.1 Step 1: Prepare Process Flow Diagram

A site-specific process flow diagram should be prepared to help identify all potential sources and types of EPCRA Section 313 chemical release and other waste management activities. A typical flow diagram is presented in Figure 4-7.

4.2.4.2 Step 2: Identify Potential Sources of Chemical Release and Other Waste Management Activities

Typical sources of EPCRA Section 313 chemicals from cleaning operations would be cleaning station exhaust vents, waste solvents, and container residue (from "empty" containers of the cleaning solution).

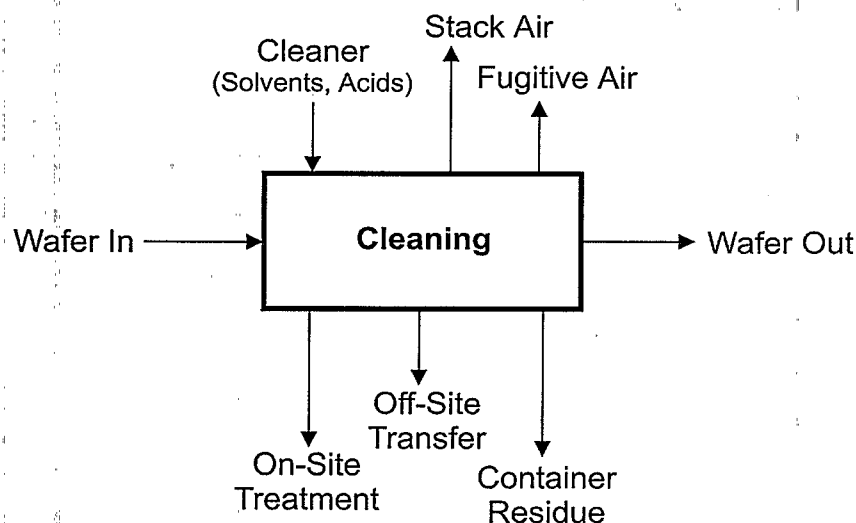


Figure 4-7. Process Flow Diagram for Typical Wafer Cleaning Process

4.2.4.3**Step 3: Identify Release and Other Waste Management Activity Types**

Release and other waste management activity types from this process include stack and fugitive air emissions; off-site transfer of the spent cleaning solutions; wastewater discharges (either direct or to a POTW); and transfers of “empty” shipping containers to off-site locations.

Typical release and other waste management activities and typical EPCRA Section 313 chemicals are:

Type of Release and Other Waste Management Activity	Typical EPCRA Section 313 Chemical
Stack Air	Hydrofluoric acid, xylene, methanol, toluene, hydrochloric acid aerosols, sulfuric acid aerosols
Fugitive Air	Hydrofluoric acid, xylene, methanol, toluene, hydrochloric acid aerosols, sulfuric acid aerosols
On-Site Treatment	Nitric acid, hydrochloric acid aerosols, sulfuric acid aerosols
Off-Site Transfer From Container Residue (off-site recycle, energy recovery, treatment, or disposal)	Xylene, methanol, toluene

Example - Cleaning

Over the course of a year, a facility uses 700,000 pounds of a 30% ammonium hydroxide solution as a cleaner. Fumes from the cleaning process are vented to a scrubber, and the scrubber water and spent developer are sent to an on-site wastewater treatment plant. You must determine whether a reporting threshold is exceeded and, if so, estimate the quantities released to the air and sent to the POTW.

Calculation Steps:

1. Determine if the threshold is exceeded for ammonia. Since ammonia is otherwise used, the reporting threshold is 10,000 lb/year. As found in Appendix D (Guidance for Reporting Aqueous Ammonia), 48.59% of ammonium hydroxide should be considered for the aqueous ammonia threshold calculations.

$$\begin{aligned}\text{Total amount of aqueous ammonia otherwise used} &= (700,000 \text{ lb NH}_4\text{OH}) \times 0.30 \times \left(\frac{17 \text{ lb NH}_3}{35 \text{ lb NH}_4\text{OH}} \right) \\ &= 102,000 \text{ lb NH}_3\end{aligned}$$

However, only 10% of total aqueous ammonia should be used for threshold determination, so

$$\begin{aligned}\text{Threshold} &= 102,000,065 \text{ (lb/year)} \times (10\%) \\ &= 10,200 \text{ (lb/year)}\end{aligned}$$

This amount exceeds the threshold for otherwise used, so an EPCRA Section 313 report must be filed for ammonia.

2. Estimate releases to the air and transfer to the POTW.

The facility has testing data that show approximately 3% of the total aqueous ammonia volatilizes (anhydrous ammonia) in the process and is sent to an on-site scrubber, which has a removal efficiency of 50 percent (this value should be reported in Section 7A of the Form R).

$$\begin{aligned}\text{Air Releases} &= (102,000 \text{ lb/year}) \times (3\%) \times (50\%) \\ &= 1,530 \text{ lb/year}\end{aligned}$$

This value should be reported in Section 5.2 of the Form R and included in the estimate for Section 8.1.

Releases to the POTW may then be estimated by subtracting the amount of ammonia released from the scrubber from the total amount of aqueous ammonia used, and adjusting to 10 % of the total.

$$\begin{aligned}\text{Releases to POTW} &= (\text{Total lb. NH}_3 - \text{Amount Released from Scrubber}) \times 10\% \\ &= (102,000 - 1,530) \times 10\% \\ &= 10,047 \text{ lb/year}\end{aligned}$$

This value should be reported in Section 6.1 of the Form R and included in the estimate for Section 8.7.

Example - Cleaning

Your facility uses methanol as a cleaner in a wet bath that is operated 5 days a week, 50 weeks per year, for 8 hours each day.

You can estimate methanol emissions using mass transfer kinetics and the following equation (from *Estimating Releases and Waste Treatment Efficiencies for the Toxic Chemical Release and Inventory Form*):

$$W_x = \frac{Mw_x \times K \times A \times P_{vap,x}}{R \times T}$$

where:	W_x	=	Evaporation rate of pollutant X (lb/sec)
	Mw_x	=	Molecular weight of pollutant X (lb/lb-mole)
	K	=	Gas-phase mass transfer coefficient (ft/sec)
		=	$0.00438 \times U^{0.78} \times (18/Mw_x)^{1/3}$
	U	=	Wind speed (miles/hr)
	A	=	Surface area (ft ²)
	$P_{vap,x}$	=	Vapor pressure of pollutant X (psia)
	R	=	Ideal gas constant (10.73 psia × ft ³ /°R × lb-mole)
	T	=	Temperature of bath (°R)

Given the following data:

Mw_x	=	32 lb methanol/lb-mole
U	=	1.7 miles/hr (default value)
A	=	1 ft ² (assumed surface area of your bath)
$P_{vap,x}$	=	1.91 psia (pure vapor pressure of methanol)
T	=	533°R, °R = (9/5) × (°C + 273)
R	=	10.73 psia × ft ³ /°R × lb-mole

First, calculate the mass transfer coefficient, K:

$$K = 0.00438 \times U^{0.78} \times (18/Mw_x)^{1/3} = 0.00547 \text{ (ft/sec)}$$

Then, calculate W_x :

$$\begin{aligned} W_x &= \frac{Mw_x \times K \times A \times P_{vap,x}}{R \times T} \\ &= \frac{(32 \text{ lb/mole}) \times (0.00547 \text{ ft/sec}) \times (1 \text{ ft}^2) \times (1.91 \text{ psia})}{(10.73 \text{ psia ft}^3/\text{°R lb-mole}) \times (533 \text{ °R})} \\ &= 5.84 \times 10^{-5} \text{ lb/sec} \end{aligned}$$

You can then calculate your annual emissions as follows:

$$\text{Annual Methanol Emissions} = \text{Emissions (lb/sec)} \times \text{operating schedule}$$

$$\begin{aligned} &= (5.84 \times 10^{-5} \text{ lb/sec}) \times \left(\frac{60 \text{ sec}}{\text{minute}} \right) \times \left(\frac{60 \text{ min}}{\text{hr}} \right) \times \left(\frac{8 \text{ hr}}{\text{day}} \right) \times \left(\frac{5 \text{ days}}{\text{wk}} \right) \times \left(\frac{50 \text{ wks}}{\text{yr}} \right) \\ &= 420 \text{ lb/yr} \end{aligned}$$

4.2.4.4

Step 4: Determine the Most Appropriate Method(s) to Calculate the Estimates for Release and Other Waste Management Activity Quantities

Fugitive and point source air emissions of organic solvents from evaporative losses can be estimated using mass balance and engineering calculations. Engineering calculations can be used to estimate inorganic acid emissions, and may be used in conjunction with a mass balance approach to estimate quantities treated on site. Because many of the EPCRA Section 313 chemicals are used in more than one process, many of the release and other waste management estimation examples presented for other processes may also be applicable here.

Quantities of EPCRA Section 313 chemicals in "empty" container residues subject to waste management can be estimated using established residue factors based on the method of cleaning or draining of the container (see Table 4-1 and the corresponding container residue example).

4.2.5

Doping

Doping is a process in which specific atoms of impurities are introduced into the silicon substrate to alter the electrical properties of the substrate by acting as charge carriers. Their concentration and type dictate the electrical characteristics that define the transistor's, and ultimately, the device's function. Doping is typically accomplished through ion implantation or diffusion processes.

Ion implantation is the most common method used to introduce impurity atoms into the wafer. It provides a more controlled doping mechanism than diffusion. The dopant atoms are first ionized with a medium-to-high-current filament, then accelerated toward the wafer surface with large magnetic and electrical fields. Precise control of the dopant ion momentum in this process allows for precise control of the penetration into the silicon substrate. Because of the high kinetic energy of the ions during bombardment, damage to the substrate's crystalline structure occurs. To restore the substrate's structure to a satisfactory level, slow

heating or "annealing" of the amorphous material in various gaseous atmospheres is subsequently performed.

Diffusion is a high-temperature process also used to introduce a controlled amount of a dopant into the silicon substrate. The process occurs in a specially designed tube furnace where dopants may be introduced in one of two primary ways: dopant gases may be introduced into the furnace that will diffuse into the exposed areas of the substrate (gaseous diffusion), or dopant atoms may diffuse into the substrate from a previously deposited dopant oxide layer in the areas where the two are in contact (nongaseous diffusion). By knowing the amount of dopant atoms and using a carefully controlled constant temperature, a predictable solid-state diffusion may be achieved.

Typical EPCRA Section 313 chemicals used in doping processes are arsenic, arsine, diborane, boron, boron trifluoride and compounds of antimony. As with thin film deposition, doping is another process where EPCRA Section 313 chemicals are intentionally introduced into the final product and are thus considered to be processed, and subject to the 25,000 pound per year processing threshold.

4.2.5.1 Step 1: Prepare Process Flow Diagram

A site-specific process flow diagram should be prepared to help identify all potential sources and types of chemical release and other waste management activities. A typical flow diagram is presented in Figure 4-8.

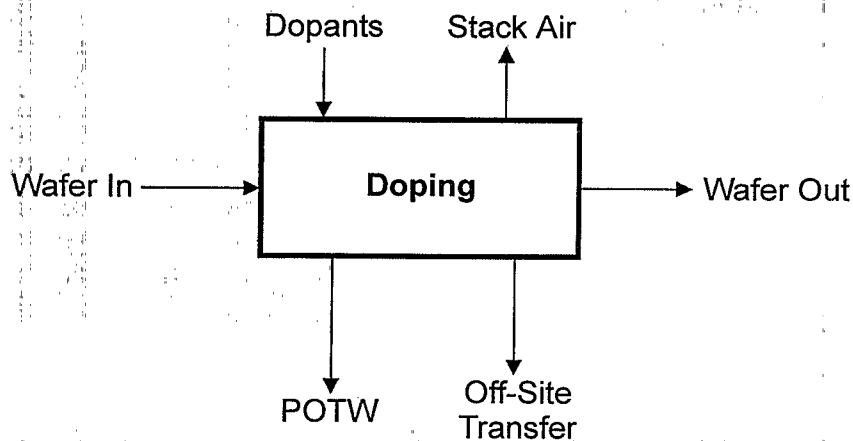


Figure 4-8. Process Flow Diagram for Typical Doping Process

4.2.5.2 Step 2: Identify Potential Sources of Chemical Release and Other Waste Management Activities

The most common potential source of EPCRA Section 313 chemicals from doping are the dopants themselves, as well as certain organic compounds which may be used as furnace cleaning gases or chlorine sources. The physical release and other waste management activity points are tool and control device exhaust vents, spent cleaning solutions, and solid or hazardous waste generated as part of the process.

4.2.5.3 Step 3: Identify Release and Other Waste Management Activity Types

Because relatively low quantities of dopant metals are used, they will not exceed the reporting threshold frequently. However, in certain cases they will and would be expected to be found in trace amounts in wastewater treatment plant effluent and solid waste shipped off site for further waste management activities. "Empty" containers or drums may also contain trace amounts of metals or other dopants.

Organic chemicals may be emitted from furnace exhaust and may also be collected and sent off site for further waste management activities.

Type of Release and Other Waste Management Activity	Typical EPCRA Section 313 Chemical
Stack Air	1,2-dichloroethylene
Off-Site Transfer	Arsenic, antimony
POTW	Trace amounts of metals

4.2.5.4 Step 4: Determine the Most Appropriate Method(s) to Calculate the Estimates for Release and Other Waste Management Activity Quantities

Release and other waste management quantities of organic compounds used as chlorine sources (also used to clean furnace interiors) may be calculated using a material balance approach or engineering calculations.

Wastewater volumes are normally metered or may be estimated based on make-up quantities required. Wastewater concentrations of EPCRA Section 313 chemicals may already be monitored in compliance with discharge or pretreatment permit requirements. Flow and concentration data can be used to determine the amount of the EPCRA Section 313 chemical managed in this fashion.

Example - Doping

Your facility uses arsenic as a dopant in a diffusion furnace. After the process has been completed, the interior of the furnace is cleaned using an inorganic acid solution and the contaminated wastewater is sent to the on-site treatment plant. You are trying to calculate releases of arsenic to the local POTW. The following data are provided:

Arsenic concentration = 0.005 mg/liter
Daily average flowrate = 40,000,000 liters/day
Operating schedule = 260 days/year

Annual releases of arsenic = (arsenic concentration in wastewater) × (Daily volume of wastewater) × (days/year)

= (0.005 mg/liter) × (40,000,000 liters/day) × (1 lb/454,000 mg) × (260 days/yr)
= 114 (lb/year)

4.2.6 Chemical Mechanical Planarization

Chemical mechanical planarization (CMP) is used in semiconductor manufacturing to remove the top layer of material from the wafer in a controlled manner, leaving

a smooth and flat surface for further processing. This technology is applied in two ways. The first is to remove selectively the top part of a nonconducting layer or film to reduce the topography on the wafer (also called planarization). The end result is an increase in the process margin for both deposition and photolithography. The second type of CMP is removal of excess material from the surface of conducting layers (metals). After a blanket pattern, conducting material is deposited on the underlayer, and the wafer is polished down to the patterned underlayer. The result is a smooth, flat surface that has conducting material left in the patterned crevices.

4.2.6.1 Step 1: Prepare Process Flow Diagram

A site-specific process flow diagram should be prepared to help identify all potential sources and types of chemical release and other waste management activities. A typical flow diagram is presented in Figure 4-9.

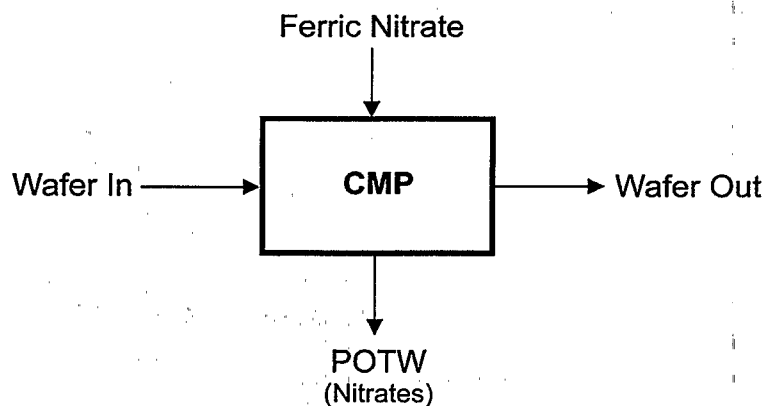


Figure 4-9. Process Flow Diagram for Typical Chemical Mechanical Planarization (CMP) Process

4.2.6.2 Step 2: Identify Potential Sources of Chemical Release and Other Waste Management Activities

The only notable source of EPCRA Section 313 chemicals from CMP is the planarization process that typically contains ferric nitrate ($\text{Fe}(\text{NO}_3)_3$). In the CMP process, this nitrate compound is considered "otherwise used" and is subject to the 10,000 lb/yr reporting

threshold. The primary point of release is the spent slurry containing nitrates, which is typically sent off-site to a POTW.

4.2.6.3 Step 3: Identify Release and Other Waste Management Activity Types

As mentioned above, discharge to a POTW is the release type expected from CMP operations. Typical release types and typical EPCRA Section 313 chemicals are:

Type of Release and Other Waste Management Activity	Typical EPCRA Section 313 Chemical
POTW	Nitrate compounds, copper

4.2.6.4 Step 4: Determine the Most Appropriate Method(s) to Calculate the Estimates for Release and Other Waste Management Activity Quantities

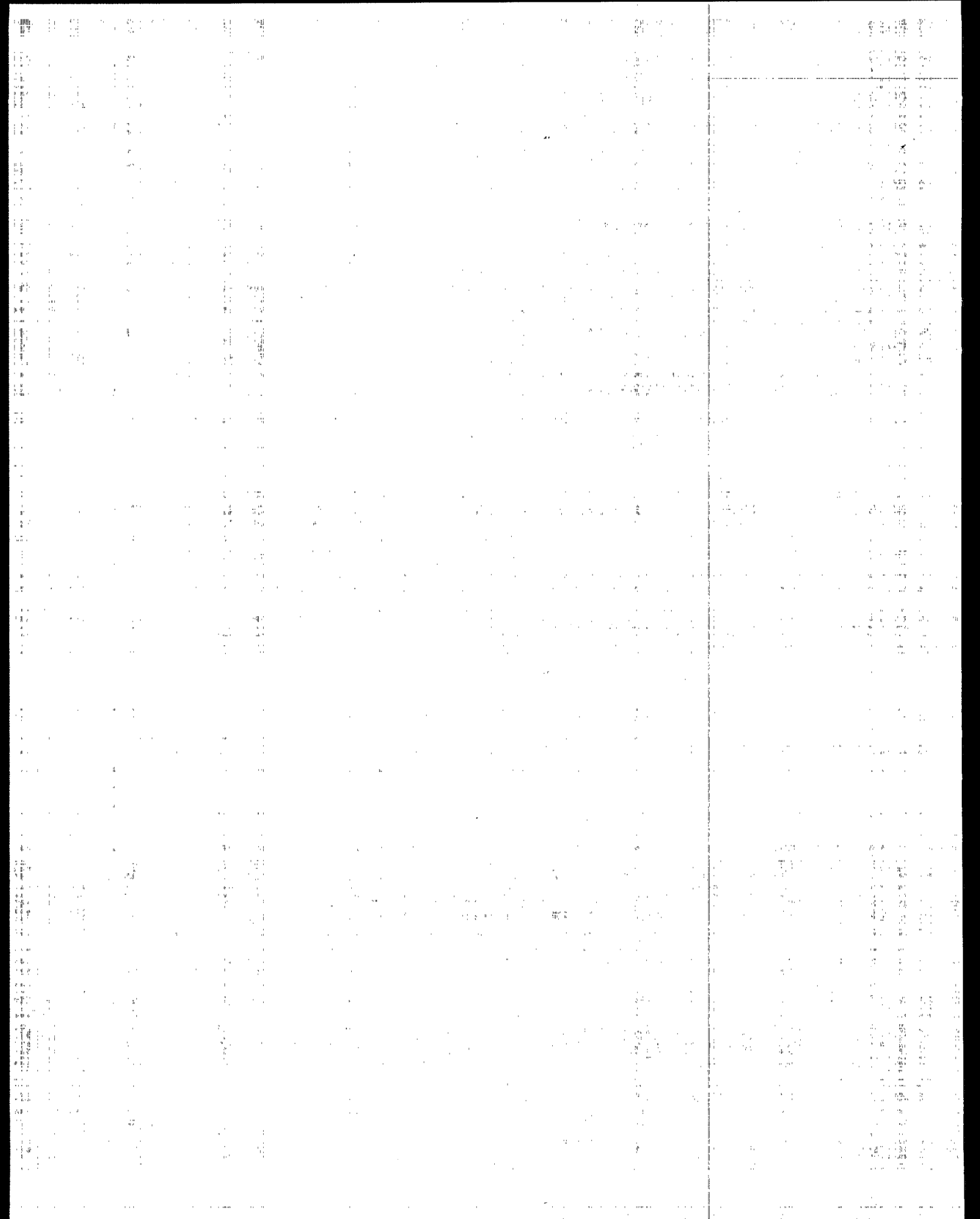
All atypical sources and types should be considered; however, if nitrate compounds from the use of ferric nitrate are the only EPCRA Section 313 chemical, the release calculation is relatively straightforward. If the amount of ferric nitrate used over the course of a year is known, releases of nitrates to the POTW may be calculated as shown in the following Example.

Example - Chemical Mechanical Planarization

Your facility uses 8,000 pounds per year of ferric nitrate in CMP operations. The spent slurry from these operations is sent to the local POTW. The reporting threshold for nitrate compounds has already been exceeded (from other operations at your facility) and you must calculate the transfer of nitrate compounds to the POTW from this operation.

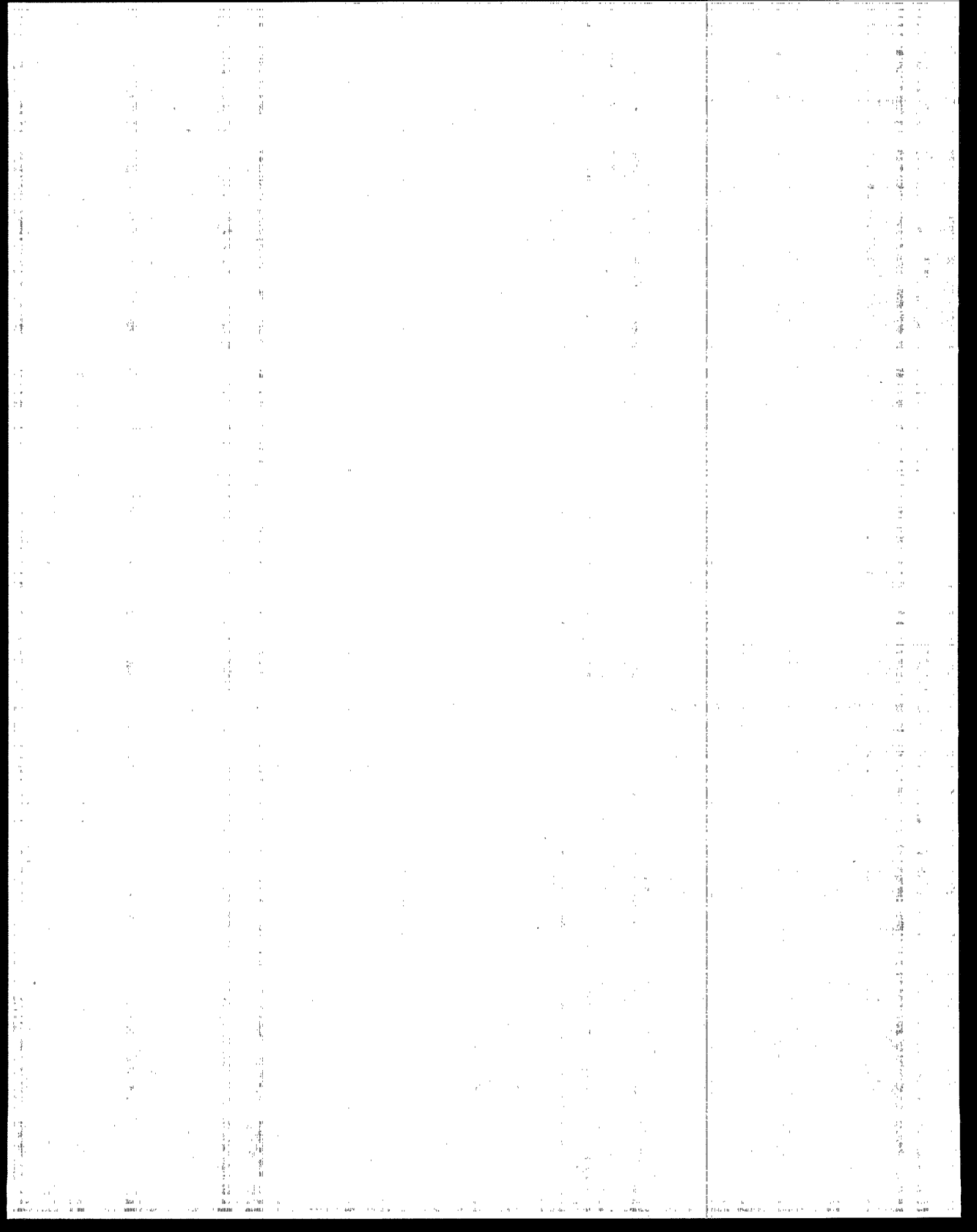
$$\begin{aligned}
 \text{Transfer to POTW} &= (\text{amount of ferric nitrate used}) \times (\text{moles of nitrate/mole of ferric nitrate}) \times \\
 &\quad (\text{ratio of the molecular weights of nitrate to ferric nitrate}) \\
 &= 8,000 \text{ lb Fe(NO}_3)_3 \times (3 \text{ moles nitrate/mol ferric nitrate}) \times (62/242) \\
 &= 6,149 \text{ lb NO}_3/\text{yr}
 \end{aligned}$$

Further information on estimating releases of nitrate compounds may be found in Appendix E.



Appendix A

TRI GUIDANCE RESOURCES



Appendix A

TRI GUIDANCE RESOURCES

A.1 EPCRA Section 313 RELATED REFERENCES

40 CFR 372, Toxic Chemical Release Reporting; Community Right-to-Know; Final Rule
See 53 FR 4500, February 16, 1988.

Toxic Chemical Release Inventory Reporting Forms and Instructions for the Current Reporting Year - See also Automated Toxic Chemical Release Inventory Reporting Software (ATRS) under Section A.2, Internet Sites.

U.S. EPA publishes this document each year to provide current guidance for preparing the Form R and Form A reports. This document contains the most up-to-date list of chemicals for which reports are required. It includes a blank Form R and Form A and provides step-by-step instructions for completing each report. It also has a list of U.S. EPA regional and state contacts for EPCRA Section 313 reporting. The current version of this document should always be consulted in preparing the EPCRA Section 313 report.

Common Synonyms for Chemicals Listed Under EPCRA Section 313 of the Emergency Planning and Community Right-to-Know Act (EPA 745-R-95-008)

This glossary contains chemical names and their synonyms for substances covered by the reporting requirements of EPCRA Section 313. The glossary was developed to aid in determining whether a facility manufactures, processes, or uses a chemical subject to EPCRA Section 313 reporting.

Consolidated List of Chemicals Subject to the Emergency Planning and Community Right-to-Know Act (EPCRA) and Section 112(r) of the Clean Air Act (as amended) (EPA 740-R-95-001)
List of chemicals covered by EPCRA Sections 302 and 313, CERCLA Hazardous Substances, and CAA 112(r). The list contains the chemical name, CAS Registry Number, and reporting requirement(s) to which the chemical is subject.

The Emergency Planning and Community Right-to-Know Act: EPCRA Section 313 Release Reporting Requirements, August, 1995 (EPA 745/K-95-052)

This brochure alerts businesses to their reporting obligations under EPCRA Section 313 and assists in determining whether their facility is required to report. The brochure contains U.S. EPA Regional contacts, the list of EPCRA Section 313 toxic chemicals and a description of the Standard Industrial Classification (SIC) codes subject to EPCRA Section 313.

EPCRA Section 313 Questions and Answers: 1998 Version, (EPA 745-B-98-004).

Executive Order 12856 - Federal Compliance with Right-to-Know Laws and Pollution Prevention Requirements: Questions and Answers (EPA 745-R-95-011)

This document assists federal facilities in complying with Executive Order 12856. This information has been compiled by U.S. EPA from questions received from federal facilities. This document is intended for the exclusive use of federal facilities in complying with Sections 302,

303, 304, 311, 312, and 313 of the Emergency Planning and Community Right-to-Know Act (EPCRA) of 1986 and the Pollution Prevention Act of 1990, as directed by the Executive Order.

Supplier Notification Requirements (EPA 560/4-91-006)

This pamphlet assists chemical suppliers who may be subject to the supplier notification requirements under EPCRA Section 313. The pamphlet explains the supplier notification requirements, gives examples of situations which require notification, describes the trade secret provision, and contains a sample notification.

Toxic Chemical Release Inventory - Data Quality Checks to Prevent Common Reporting Errors on Form R/Form A (EPA 745-R-98-012)

This is a compilation of Notices of Data Change, Significant Error, Noncompliance, or Technical Error. It provides a listing of common errors found on the Form R reports submitted to U.S. EPA. It also provides a discussion of the types of errors which result in each of the above Notices as well as a list of Notice of Technical Error codes and descriptions.

Trade Secrets Rule and Form

See 53 FR 28772, July 29, 1988. This rule implements the trade secrets provision of the EPCRA (Section 322) and includes a copy of the trade secret substantiation form.

A.2 INFORMATION SOURCES

Most of the materials included as reference in this manual are available from the following sources:

National Center for Environmental Publications and Information (NCEPI)
P.O. Box 42419
Cincinnati, OH 45242-2419
(800) 490-9198
Fax: (513)489-8695
Internet: <http://www.epa.gov/ncepihom/index.html>

Emergency Planning and Community Right-to-Know (EPCRA) Information Hotline
U.S. Environmental Protection Agency
(800) 424-9346 or (703) 412-9810 (for the Washington, D.C. metropolitan area)
TDD: (800) 553-7672

Internet Sites

- TRI homepage: <http://www.epa.gov/opptintr/tri>
This site contains information on the Toxic Release Inventory and provides links to a variety of data and documents related to the TRI program.
- Automated Toxic Chemical Release Inventory Reporting Software (ATRS):
<http://www.epa.gov/opptintr/atrs>
This site provides access to the automated EPCRA Section 313 reporting forms for electronic submittal of required data to U.S. EPA.

- **Air CHIEF CD-ROM**
<http://www.epa.gov/ttn/chief/airchief.html>
 This site provides information on the Air CHIEF CD-ROM, contents, ordering information, system requirements, and sources for additional information.
- **Clearinghouse for Inventories and Emission Factors (CHIEF):**
<http://www.epa.gov/ttn/chief/>
 This site provides access to the latest information and tools for estimating emissions of air pollutants and performing emission inventories.
- **Code of Federal Regulations, 40 CFR:** <http://www.epa.gov/epacfr40>
 This site was created by U.S. EPA to expand access to Title 40 - Environmental Protections of the Code of Federal Regulations.
- **Compilation of Air Pollutant Emission Factors (AP-42):**
<http://www.epa.gov/ttn/chief/ap42etc.html>
 This site provides access to files containing guidance for estimating emissions from specific sources and emission factors.
- **Federal Register Notice:** <http://www.epa.gov/EPA-TRI>
 This site provides access to all Federal Register notices related to the TRI program from 1994 to current.
- **Material Safety Data Sheets (MSDSs):**
<http://msds.pdc.cornell.edu/issearch/msdssrch.htm>
 A key word searchable database of 325,000 MSDSs.
- **TANKS:** <http://www.epa.gov/ttn/chief/tanks.html>
 This site contains information on TANKS, a DOS-based computer software program that computes estimates of VOC emissions from fixed and floating-roof storage tanks.
- **WATER8/CHEMDAT8:** <http://www.epa.gov/ttn/chief/software.html#water8>
 WATER8 is an analytical model for estimating compound-specific air emissions from wastewater collection and treatment systems. CHEMDAT8 is a Lotus 1-2-3 spreadsheet for estimating VOC emissions from TSDF processes.

National Technical Information Service (NTIS)

U.S. Department of Commerce

5285 Port Royal Road

Springfield, VA 22161

Call: (800) 553-6847; (703) 487-4650

Fax: (703) 321-8547

Publication Number PB97-502-587

E-mail: info@ntis.fedworld.gov

A.3 INDUSTRY-SPECIFIC TECHNICAL GUIDANCE DOCUMENTS

In 1988 and 1990, U.S. EPA developed a group of individual guidance documents for industries or activities in industries who primarily manufacture, process, or otherwise use EPCRA Section 313 chemicals. See list of industries/activities below. U.S. EPA is currently revising some of these documents and preparing additional documents. The newer versions will be available beginning in the Fall of 1998.

Chemical Distribution Facilities, January 1999 (EPA 745-B-99-005)

Coal Mining Facilities, January 1999 (EPA 745-B-99-002)

Coincidental Manufacture/By-products

Electricity Generating Facilities, January 1999 (EPA 745-B-99-003)

Estimating Releases and Waste Treatment Efficiencies

Food Processors, September 1998 (EPA 745-R-98-011)

Formulation of Aqueous Solutions, March 1988 (EPA 560-4-88-004F)

Foundry Operations

Leather Tanning and Finishing Industry

Metal Mining Facilities, January 1999 (EPA 745-B-99-001)

Metal Fabrication and Electroplating Operations

Monofilament Fiber Manufacture

Paper and Paperboard Production

Petroleum Terminals and Bulk Storage Facilities, January 1999 (EPA 745-B-99-006)

Presswood & Laminated Wood Products Manufacturing

Printing Industry

RCRA Subtitle C TSD Facilities and Solvent Recovery Facilities, January 1999 (EPA 745-B-99-004)

Roller, Knife, and Gravure Coating Operations

Rubber and Plastics Manufacturing

Semiconductor Manufacture

Smelting Operations

Spray Application and Electrodeposition of Organic Coatings, December 1998 (EPA 745-B-99-014)

Textile Processing Industry

Welding Operations

Wood Preserving Operations

U.S. EPA, Office of Compliance, published a series of documents in 1995 called Sector Notebooks. These documents provide information of general interest regarding environmental issues associated with specific industrial sectors. The Document Control Numbers (DCN) range from EPA/310-R-95-001 through EPA/310-R-95-018.

A.4 CHEMICAL-SPECIFIC GUIDANCE DOCUMENTS

U.S. EPA has also developed a group of guidance documents specific to individual chemicals and chemical categories. These are presented below.

Emergency Planning and Community Right-to-Know EPCRA Section 313: Guidance for Reporting Aqueous Ammonia, July 1995 (EPA 745-R-95-012)

Emergency Planning and Community Right-to-Know EPCRA Section 313: List of Toxic Chemicals within the Chlorophenols Category, November 1995 (EPA 745-B-95-004)

Estimating Releases for Mineral Acid Discharges Using pH Measurements, U.S. Environmental Protection Agency, June 1991.

Guidance for Reporting Sulfuric Acid (acid aerosols including mists, vapors, gas, fog, and other airborne forms of any particle size), November 1997 (EPA-745-R-97-007)

Toxic Release Inventory List of Toxic Chemicals within the Glycol Ethers Category and Guidance for Reporting, May 1995 (EPA 745-R-95-006)

Toxic Release Inventory List of Toxic Chemicals within the Nicotine and Salts Category and Guidance for Reporting, February 1995 (EPA 745-R-95-004)

Toxic Release Inventory List of Toxic Chemicals within the Polychlorinated Alkanes Category and Guidance for Reporting, February 1995 (EPA 745-R-95-001)

Toxic Release Inventory List of Toxic of Chemicals within the Polycyclic Aromatic Compounds Category, February 1995 (EPA 745-R-95-003)

Toxic Release Inventory List of Toxic Chemicals within the Strychnine and Salts Category and Guidance for Reporting, February 1995 (EPA 745-R-95-005)

Toxic Release Inventory List of Toxic of Chemicals within the Water Dissociable Nitrate Compounds Category and Guidance for Reporting, May, 1996 (EPA 745-R-96-004)

Toxics Release Inventory - List of Toxic Chemicals Within Ethylenebisdithiocarbamic Acid Category, November 1994, EPA 745-B-94-003.

Toxics Release Inventory - Copper Phthalocyanine Compounds Excluded for the Reporting Requirements Under the Copper Compounds Category on the EPCRA Section 313 List, April 1995, EPA 745-R-95-007.

Toxics Release Inventory - List of Toxic Chemicals Within Warfarin Category, November 1994, EPA 745-B-94-004.

A.5 OTHER USEFUL REFERENCES

Burgess, W.A. Recognition of Health Hazards in Industry. Harvard School of Public Health. Boston, Massachusetts, John-Wiley & Sons.

CRC Handbook of Chemistry and Physics. Latest Edition, Robert C. Weast, Editor, CRC Press, Inc., Florida.

Kirk Othmer - Encyclopedia of Chemical Technology. Latest Edition, John Wiley & Sons, New York.

Locating and Estimating Air Emissions from Various Sources. Available from: National Technical Information Services (NTIS), (703) 487-4650.

The Merck Index. Latest Edition, Merck & Co., Inc., New Jersey.

Perry, R.H. and C.H. Chilton, Chemical Engineer's Handbook. Latest Edition, McGraw-Hill Book Company, New York.

Sax, N.I. and R.J. Lewis, Sr., Hawley's Condensed Chemical Dictionary. Latest Edition, Van Nostrand Reinhold Company, New York.

Appendix B

BASIC CALCULATION TECHNIQUES

1. 材料費	100	100	
2. 労務費	200	200	
3. 経費	50	50	
4. 利益	50	50	
5. 合計	400	400	
6. 売上高	400	400	
7. 粗利益	100	100	
8. 経費	50	50	
9. 利益	50	50	
10. 合計	200	200	
11. 売上高	200	200	
12. 粗利益	50	50	
13. 経費	25	25	
14. 利益	25	25	
15. 合計	100	100	
16. 売上高	100	100	
17. 粗利益	25	25	
18. 経費	12.5	12.5	
19. 利益	12.5	12.5	
20. 合計	50	50	
21. 売上高	50	50	
22. 粗利益	12.5	12.5	
23. 経費	6.25	6.25	
24. 利益	6.25	6.25	
25. 合計	25	25	
26. 売上高	25	25	
27. 粗利益	6.25	6.25	
28. 経費	3.125	3.125	
29. 利益	3.125	3.125	
30. 合計	12.5	12.5	
31. 売上高	12.5	12.5	
32. 粗利益	3.125	3.125	
33. 経費	1.5625	1.5625	
34. 利益	1.5625	1.5625	
35. 合計	6.25	6.25	
36. 売上高	6.25	6.25	
37. 粗利益	1.5625	1.5625	
38. 経費	0.78125	0.78125	
39. 利益	0.78125	0.78125	
40. 合計	3.125	3.125	
41. 売上高	3.125	3.125	
42. 粗利益	0.78125	0.78125	
43. 経費	0.390625	0.390625	
44. 利益	0.390625	0.390625	
45. 合計	1.5625	1.5625	
46. 売上高	1.5625	1.5625	
47. 粗利益	0.390625	0.390625	
48. 経費	0.1953125	0.1953125	
49. 利益	0.1953125	0.1953125	
50. 合計	0.78125	0.78125	
51. 売上高	0.78125	0.78125	
52. 粗利益	0.1953125	0.1953125	
53. 経費	0.09765625	0.09765625	
54. 利益	0.09765625	0.09765625	
55. 合計	0.390625	0.390625	
56. 売上高	0.390625	0.390625	
57. 粗利益	0.09765625	0.09765625	
58. 経費	0.048828125	0.048828125	
59. 利益	0.048828125	0.048828125	
60. 合計	0.1953125	0.1953125	
61. 売上高	0.1953125	0.1953125	
62. 粗利益	0.048828125	0.048828125	
63. 経費	0.0244140625	0.0244140625	
64. 利益	0.0244140625	0.0244140625	
65. 合計	0.09765625	0.09765625	
66. 売上高	0.09765625	0.09765625	
67. 粗利益	0.0244140625	0.0244140625	
68. 経費	0.01220703125	0.01220703125	
69. 利益	0.01220703125	0.01220703125	
70. 合計	0.048828125	0.048828125	
71. 売上高	0.048828125	0.048828125	
72. 粗利益	0.01220703125	0.01220703125	
73. 経費	0.006103515625	0.006103515625	
74. 利益	0.006103515625	0.006103515625	
75. 合計	0.0244140625	0.0244140625	
76. 売上高	0.0244140625	0.0244140625	
77. 粗利益	0.006103515625	0.006103515625	
78. 経費	0.0030517578125	0.0030517578125	
79. 利益	0.0030517578125	0.0030517578125	
80. 合計	0.01220703125	0.01220703125	
81. 売上高	0.01220703125	0.01220703125	
82. 粗利益	0.0030517578125	0.0030517578125	
83. 経費	0.00152587890625	0.00152587890625	
84. 利益	0.00152587890625	0.00152587890625	
85. 合計	0.006103515625	0.006103515625	
86. 売上高	0.006103515625	0.006103515625	
87. 粗利益	0.00152587890625	0.00152587890625	
88. 経費	0.000762939453125	0.000762939453125	
89. 利益	0.000762939453125	0.000762939453125	
90. 合計	0.0030517578125	0.0030517578125	
91. 売上高	0.0030517578125	0.0030517578125	
92. 粗利益	0.000762939453125	0.000762939453125	
93. 経費	0.0003814697265625	0.0003814697265625	
94. 利益	0.0003814697265625	0.0003814697265625	
95. 合計	0.00152587890625	0.00152587890625	
96. 売上高	0.00152587890625	0.00152587890625	
97. 粗利益	0.0003814697265625	0.0003814697265625	
98. 経費	0.00019073486328125	0.00019073486328125	
99. 利益	0.00019073486328125	0.00019073486328125	
100. 合計	0.000762939453125	0.000762939453125	
101. 売上高	0.000762939453125	0.000762939453125	
102. 粗利益	0.00019073486328125	0.00019073486328125	
103. 経費	0.000095367431640625	0.000095367431640625	
104. 利益	0.000095367431640625	0.000095367431640625	
105. 合計	0.0003814697265625	0.0003814697265625	
106. 売上高	0.0003814697265625	0.0003814697265625	
107. 粗利益	0.000095367431640625	0.000095367431640625	
108. 経費	0.0000476837158203125	0.0000476837158203125	
109. 利益	0.0000476837158203125	0.0000476837158203125	
110. 合計	0.00019073486328125	0.00019073486328125	
111. 売上高	0.00019073486328125	0.00019073486328125	
112. 粗利益	0.0000476837158203125	0.0000476837158203125	
113. 経費	0.00002384185791015625	0.00002384185791015625	
114. 利益	0.00002384185791015625	0.00002384185791015625	
115. 合計	0.000095367431640625	0.000095367431640625	
116. 売上高	0.000095367431640625	0.000095367431640625	
117. 粗利益	0.00002384185791015625	0.00002384185791015625	
118. 経費	0.000011920928955078125	0.000011920928955078125	
119. 利益	0.000011920928955078125	0.000011920928955078125	
120. 合計	0.0000476837158203125	0.0000476837158203125	
121. 売上高	0.0000476837158203125	0.0000476837158203125	
122. 粗利益	0.000011920928955078125	0.000011920928955078125	
123. 経費	0.0000059604644775390625	0.0000059604644775390625	
124. 利益	0.0000059604644775390625	0.0000059604644775390625	
125. 合計	0.00002384185791015625	0.00002384185791015625	
126. 売上高	0.00002384185791015625	0.00002384185791015625	
127. 粗利益	0.0000059604644775390625	0.0000059604644775390625	
128. 経費	0.00000298023223876953125	0.00000298023223876953125	
129. 利益	0.00000298023223876953125	0.00000298023223876953125	
130. 合計	0.000011920928955078125	0.000011920928955078125	
131. 売上高	0.000011920928955078125	0.000011920928955078125	
132. 粗利益	0.00000298023223876953125	0.00000298023223876953125	
133. 経費	0.000001490116119384765625	0.000001490116119384765625	
134. 利益	0.000001490116119384765625	0.000001490116119384765625	
135. 合計	0.0000059604644775390625	0.0000059604644775390625	
136. 売上高	0.0000059604644775390625	0.0000059604644775390625	
137. 粗利益	0.000001490116119384765625	0.000001490116119384765625	
138. 経費	0.0000007450580596923828125	0.0000007450580596923828125	
139. 利益	0.0000007450580596923828125	0.0000007450580596923828125	
140. 合計	0.00000298023223876953125	0.00000298023223876953125	
141. 売上高	0.00000298023223876953125	0.00000298023223876953125	
142. 粗利益	0.0000007450580596923828125	0.0000007450580596923828125	
143. 経費	0.00000037252902984619140625	0.00000037252902984619140625	
144. 利益	0.00000037252902984619140625	0.00000037252902984619140625	
145. 合計	0.000001490116119384765625	0.000001490116119384765625	
146. 売上高	0.000001490116119384765625	0.000001490116119384765625	
147. 粗利益	0.00000037252902984619140625	0.00000037252902984619140625	
148. 経費	0.000000186264514923095703125	0.000000186264514923095703125	
149. 利益	0.000000186264514923095703125	0.000000186264514923095703125	
150. 合計	0.0000007450580596923828125	0.0000007450580596923828125	
151. 売上高	0.0000007450580596923828125	0.0000007450580596923828125	
152. 粗利益	0.000000186264514923095703125	0.000000186264514923095703125	
153. 経費	0.0000000931322574615478515625	0.0000000931322574615478515625	
154. 利益	0.0000000931322574615478515625	0.0000000931322574615478515625	
155. 合計	0.00000037252902984619140625	0.00000037252902984619140625	
156. 売上高	0.00000037252902984619140625	0.00000037252902984619140625	
157. 粗利益	0.0000000931322574615478515625	0.0000000931322574615478515625	
158. 経費	0.00000004656612873077392578125	0.00000004656612873077392578125	
159. 利益	0.00000004656612873077392578125	0.00000004656612873077392578125	
160. 合計	0.000000186264514923095703125	0.000000186264514923095703125	
161. 売上高	0.000000186264514923095703125	0.000000186264514923095703125	
162. 粗利益	0.00000004656612873077392578125	0.00000004656612873077392578125	
163. 経費	0.000000023283064365386962890625	0.000000023283064365386962890625	
164. 利益	0.000000023283064365386962890625	0.000000023283064365386962890625	
165. 合計	0.0000000931322574615478515625	0.0000000931322574615478515625	
166. 売上高	0.0000000931322574615478515625	0.0000000931322574615478515625	
167. 粗利益	0.000000023283064365386962890625	0.000000023283064365386962890625	
168. 経費	0.0000000116415321826934814453125	0.0000000116415321826934814453125	
169. 利益	0.0000000116415321826934814453125	0.0000000116415321826934814453125	
170. 合計	0.00000004656612873077392578125	0.00000004656612873077392578125	
171. 売上高	0.00000004656612873077392578125	0.00000004656612873077392578125	
172. 粗利益	0.0000000116415321826934814453125	0.0000000116415321826934814453125	
173. 経費	0.00000000582076609134674072265625	0.00000000582076609134674072265625	
174. 利益	0.00000000582076609134674072265625	0.00000000582076609134674072265625	
175. 合計	0.000000023283064365386962890625	0.000000023283064365386962890625	
176. 売上高	0.000000023283064365386962890625	0.000000023283064365386962890625	
177. 粗利益	0.00000000582076609134674072265625	0.00000000582076609134674072265625	
178. 経費	0.000000002910383045673370361328125	0.000000002910383045673370361328125	
179. 利益	0.000000002910383045673370361328125	0.000000002910383045673370361328125	
180. 合計	0.0000000116415321826934814453125	0.0000000116415321826934814453125	
181. 売上高	0.0000000116415321826934814453125	0.0000000116415321826934814453125	
182. 粗利益	0.000000002910383045673370361328125	0.000000002910383045673370361328125	
183. 経費	0.0000000014551915228366851806640625	0.0000000014551915228366851806640625	
184. 利益	0.0000000014551915228366851806640625	0.0000000014551915228366851806640625	
185. 合計	0.00000000582076609134674072265625	0.00000000582076609134674072265625	
186. 売上高	0.00000000582076609134674072265625	0.00000000582076609134674072265625	
187. 粗利益	0.0000000014551915228366851806640625	0.0000000014551915228366851806640625	
188. 経費	0.00000000072759576141834259033203125	0.00000000072759576141834259033203125	
189. 利益	0.00000000072759576141834259033203125	0.00000000072759576141834259033203125	
190. 合計	0.000000002910383045673370361328125	0.000000002910383045673370361328125	
191. 売上高	0.000000002910383045673370361328125	0.000000002910383045673370361328125	
192. 粗利益	0.00000000072759576141834259033203125	0.00000000072759576141834259033	

Appendix B

BASIC CALCULATION TECHNIQUES

This section will provide the basic techniques needed to use specific types of data or engineering calculations. Examples are provided for:

- (1) Stack monitoring data;
- (2) Industrial hygiene data;
- (3) Raoult's Law;
- (4) Air emission factors;
- (5) RCRA hazardous waste analysis data;
- (6) NPDES monitoring data.

(1) **Stack Monitoring Data**

The following is an example of a release calculation using monitoring data.

Example: Stack monitoring data are available for a paint booth. The measured average concentration of toluene is 0.1 ppmv (dry gas basis). The moisture content in the stack is typically 10%, and stack conditions are maintained at 80°C and atmospheric pressure. The stack gas velocity is 8 m/s. The diameter of the stack is 0.3 m. Calculate the point air release of toluene.

Step 1. Calculate volumetric flow of stack gas stream.

$$\text{Volumetric flow} = (\text{gas velocity}) \times [(\pi) \times (\text{internal stack diameter})^2/4]$$

$$\text{Volumetric flow} = (8.0 \text{ m/s}) \times [(\pi) \times (0.3 \text{ m})^2/4] = 0.6 \text{ m}^3/\text{s}$$

Step 2. Correct for moisture content in stack gas stream.

Stack exhausts may contain large amounts of water vapor. The concentration of the chemical in the exhaust is often presented on a dry basis. For an accurate release rate, correct the vent gas flow rate for the moisture content by multiplying by the term (1 - fraction water vapor). The dry gas rate can then be multiplied by the chemical concentration.

(Note: If the toluene concentration is on a wet gas basis, no correction is necessary for moisture content.)

$$\text{Dry volumetric flow} = (\text{Volumetric flow}) \times (1 - \text{fraction water vapor})$$

$$\text{Dry volumetric flow} = (0.6 \text{ m}^3/\text{s}) \times (1 - 0.10) = 0.5 \text{ m}^3/\text{s}$$

Step 3. Convert ppmv to mg/m³.

- ppmv is defined as one part of a chemical in 10⁶ parts of gas (1.0 m³/10⁶ m³).
- Use the molar volume of a gas, corrected for stack temperature and pressure conditions, calculated by the ideal gas law ($PV = nRT$). Note that the molar volume of an ideal gas at 237 K and 1 atm is 22.4 L/mole.
- Molecular weight of toluene (MW) = 92.14 g/mole.

R = the Ideal Gas Constant (0.082057 L - atm per mole-Kelvin)

To calculate the molar volume of stack gas, use the ideal gas equation.

$$\text{Molar volume} = \frac{V}{n} = \frac{RT}{P}$$

For the example, the stack conditions are 80° C (353 K) and atmospheric pressure (1 atm).

$$\text{Molar volume} = \left(0.082057 \frac{\text{L-atm}}{\text{mole-K}} \right) \times (353 \text{ K}) / (1 \text{ atm})$$

$$= 29.0 \text{ L/mole}$$

The conversion of ppmv to mg/m³ can now be calculated.

$$\left(\frac{\text{mg}}{\text{m}^3} \right) = (\text{concentration of chemical, ppmv}) \times \left(\frac{1}{\text{molar volume of gas}} \right) \times (\text{MW})$$

Using the example, the concentration of toluene is calculated as follows:

$$\left(\frac{0.1 \text{ m}^3}{10^6 \text{ m}^3} \right) \times \left(\frac{\text{mole}}{29.0 \text{ L}} \right) \times \left(\frac{92.14 \text{ g}}{\text{mole}} \right) \times \left(\frac{\text{L}}{10^{-3} \text{ m}^3} \right) \times \left(\frac{1,000 \text{ mg}}{1 \text{ g}} \right) = 0.3 \text{ mg/m}^3$$

Step 4. Calculate air releases.

Air releases are calculated as follows:

$$\text{Air Release} = (\text{volumetric flow, m}^3/\text{s}) \times (\text{concentration, mg/m}^3) \times (\text{operating time, s/yr})$$

The paint booth is used 8 hours per day, 5 days per week, 52 weeks per year.

$$\text{Operating time} = \left(8 \frac{\text{hr}}{\text{day}} \right) \times \left(5 \frac{\text{day}}{\text{week}} \right) \times \left(52 \frac{\text{week}}{\text{yr}} \right) = 2,080 \text{ hr/yr}$$

$$\begin{aligned} \text{Air Release} &= (0.5 \text{ m}^3/\text{s}) \times (0.3 \text{ mg/m}^3) \times \left(\frac{3,600 \text{ s}}{\text{hr}} \right) \times \left(\frac{2,080 \text{ hr}}{\text{yr}} \right) \times \left(\frac{\text{lb}}{454 \text{ g}} \right) \times \left(\frac{\text{g}}{1,000 \text{ mg}} \right) \\ &= 2.5 \text{ lb/yr of toluene} \end{aligned}$$

It is important to note that this calculation assumes the measured emissions are representative of actual emissions at all times; however, this is not always the case. Ideally, a continuous emissions monitor provides the most representative data.

Also note that monitoring and stack data may have units that are different than those used in the example. Modify conversion factors and constants to reflect your data when calculating air releases.

(2) **Industrial Hygiene Data**

The following is an example of a release calculation using industrial hygiene data.

Example: Occupational industrial hygiene data shows that workers are exposed to an average of 0.1 ppmv benzene (wet gas basis). The density of benzene vapor is 0.2 lb/ft³. The ventilation system exhausts 20,000 acfm of room air at 70°F. The plant operates 24 hours per day, 330 days per year.

The benzene concentration is on a wet gas basis, therefore a moisture correction of the ventilation flow rate is not necessary. The industrial hygiene data is collected at the same ambient conditions as the ventilation system, therefore no

adjustment for temperature or pressure needs to be performed. A conservative estimation of benzene fugitive releases could be calculated as follows:

$$\text{Air Release} = (\text{ventilation flow rate, ft}^3/\text{min}) \times (\text{operating time, min/yr}) \times (\text{concentration of chemical, ppmv}) \times (\text{vapor density of chemical, lb/ft}^3)$$

Benzene releases per year would be calculated as follows:

$$\left(\frac{20,000 \text{ ft}^3}{\text{min}} \right) \times \left(\frac{60 \text{ min}}{\text{hr}} \right) \times \left(\frac{24 \text{ hr}}{\text{day}} \right) \times \left(\frac{330 \text{ day}}{\text{yr}} \right) \times \left(\frac{0.1 \text{ ft}^3 \text{ benzene}}{10^6 \text{ ft}^3 \text{ air}} \right) \times \left(\frac{0.2 \text{ lb}}{\text{ft}^3} \right) = 190 \text{ lb/yr of benzene}$$

(3) Raoult's Law

The following is an example of a release calculation using Raoult's Law. Raoult's Law states that the partial pressure of a compound in the vapor phase over a solution may be estimated by multiplying its mole fraction in the liquid solution by the vapor pressure of the pure chemical.

$$P_A = X_{A,L}P^\circ = X_{A,G}P_T$$

where:

P°	=	Vapor pressure of pure liquid chemical A;
$X_{A,L}$	=	Mole fraction of chemical A in solution;
$X_{A,G}$	=	Mole fraction of chemical A in the gas phase;
P_A	=	Partial pressure of chemical A in the gas phase; and
P_T	=	Total pressure.

Example: A wash tank holds a solution containing 10% by weight of o-xylene (A) and 90% by weight of toluene (B). The tank is vented to the atmosphere; the process vent flow rate is estimated as 100 acfm (2.83m³/min) based on a minimum fresh air ventilation rate. The molecular weight of o-xylene is 106.17 g/mole and toluene is 92.14 g/mole. The vapor pressure of o-xylene is 10 mm of Hg (0.19 psia). The total pressure of the system is 14.7 psia (atmospheric conditions). The process tank is in service 250 days/yr. Calculate the air release of o-xylene.

Step 1: Calculate the mole fraction of o-xylene in the liquid solution.

$$X_{A,L} = \frac{\frac{\text{wt fraction A}}{MW_A}}{\frac{\text{wt fraction A}}{MW_A} + \frac{\text{wt fraction B}}{MW_B}}$$

Where:

$X_{A,L}$ = Mole fraction of chemical A in liquid solution;
 MW = Molecular weight of chemical, g/mole; and
 wt fraction = Weight fraction of chemical in material.

$$X_{A,L} = \frac{\left[\frac{0.1}{106.17} \right]}{\left[\frac{0.1}{106.17} + \frac{0.9}{92.14} \right]}$$

$$X_{A,L} = 0.09$$

Step 2: Calculate the mole fraction of o-xylene in the gas phase.

$$X_{A,G} = \frac{X_{A,L} P^{\circ}}{P_T}$$

where:

$X_{A,G}$ = Mole fraction of chemical A in gas phase;
 $X_{A,L}$ = Mole fraction of chemical A in liquid solution;
 P° = Vapor pressure of pure liquid chemical A, psia; and
 P_T = Total pressure of system, psia.

$$X_{A,G} = [0.09] \times \left[\frac{0.19 \text{ psia}}{14.7 \text{ psia}} \right] = 0.001$$

Step 3: Calculate releases using Raoult's Law.

$$\text{Emissions} = (X_{A,G}) \times (\text{AFR}) \times (t) \times (\text{MW}_A) \times \left(\frac{1}{\text{MV}} \right)$$

where:

Emissions = Air release of pollutant A, g-A/yr;
 $X_{A,G}$ = Mole fraction of chemical A in gas phase;
 AFR = Air flow rate of room, m³/min;
 t = Operating time of wash tank, min/yr;
 MW = Molecular weight of chemical, g/g-mole; and
 MV = Gas molar volume (22.4 L/mole at standard temperature and pressure).

If conditions vary from standard temperature and pressure the gas molar volume can be calculated using the ideal gas law and tank conditions as presented in Example 1.

$$\text{Emissions} = (0.001) \times$$

$$\left(\frac{2.83 \text{ m}^3}{\text{min}} \right) \times \left(\frac{250 \text{ day}}{\text{yr}} \right) \times \left(\frac{24 \text{ hr}}{\text{day}} \right) \times \left(\frac{60 \text{ min}}{\text{hr}} \right) \times \left(\frac{\text{mole}}{22.4 \text{ L}} \right) \times \left(\frac{106.17 \text{ g}}{\text{mole}} \right) \times \left(\frac{\text{L}}{10^{-3} \text{ m}^3} \right)$$

$$= 4.8 \times 10^6 \text{ g/yr}$$

The emission of o-xylene is calculated as shown below.

$$\text{Emissions} = (4.8 \times 10^6 \text{ g/yr}) \times \left(\frac{\text{lb}}{454 \text{ g}} \right) = 10,570 \text{ lb/yr of o-xylene}$$

Air releases for toluene can be calculated in a similar manner.

(4) Air Emission Factor

The following is an example of a release calculation using air emission factors.

Example: An industrial boiler uses 300 gallons per hour of No. 2 fuel oil. The boiler operates 2,000 hours per year. Calculate emissions of formaldehyde using the AP-42 emission factors.

$$\text{AE} = (\text{EF}) \times (\text{AU}) \times (\text{OT})$$

where:

- AE = Annual emissions of pollutant, lb/yr
EF = Emission factor of pollutant, lb/10³ gallon of fuel. EF for formaldehyde for an industrial boiler burning No. 2 fuel oil is 0.035 to 0.061 lb/10³ gallons.
AU = Quantity of fuel used, gal/yr.
OT = Operating time, hr/yr.

Using an emission factor of 0.061 pounds of formaldehyde per gallon of fuel, the air releases are calculated as follows:

$$AE = \left(\frac{0.061 \text{ lb}}{10^3 \text{ gal}} \right) \times \left(\frac{300 \text{ gal}}{\text{hr}} \right) \times \left(\frac{2,000 \text{ hr}}{\text{yr}} \right) = 36.6 \text{ lb/yr of formaldehyde}$$

(5) **RCRA Waste Analysis**

The following is an example of a calculation using RCRA waste analysis data.

Example: Spent paint wastes were disposed at an off-site waste treatment facility. The quantity of paint waste shipped was five 55-gallon drums per year. Analysis of the waste showed 5% cadmium by weight. Estimating the density of the paint waste to be 9.5 lb/gallon, the amount of cadmium to off-site disposal is calculated as follows:

$$\text{Amount of cadmium} = (\text{amount of paint waste disposed, gal/yr}) \times (\text{concentration of cadmium, lb/lb}) \times (\text{density of paint waste, lb/gal})$$

$$\left(\frac{5 \text{ drums}}{\text{yr}} \right) \times \left(\frac{55 \text{ gal}}{\text{drum}} \right) \times \left(\frac{9.5 \text{ lb}}{\text{gal}} \right) \times \left(\frac{5 \text{ lb Cd}}{100 \text{ lb waste}} \right) = 131 \text{ lb/yr of cadmium}$$

(6) **NPDES Data**

The following is an example of a calculation using NPDES data.

NPDES permits require periodic monitoring of the effluent stream. In this example, quarterly samples were taken to be analyzed for silver content. Each sample was an hourly, flowrate-based composite taken for one day to be representative of the discharge for that day. The total effluent volume for that day was also recorded. The following data were collected on each sample day.

Yearly Quarter Sample Number	Discharge Flow Rate (10 ⁶ gal/day)	Total Silver (µg/L)
1	0.5	10
2	0.6	10
3	0.4	6
4	0.2	<3

To calculate the amount of silver in pounds discharged on each sample day, the concentration of silver in the discharge is multiplied by the discharge flow rate for that day, as shown below for the first quarter sample.

$$\text{Amount of silver} = (\text{daily flow rate}) \times (\text{silver concentration})$$

$$\begin{aligned} \text{First Quarter: } & \left(\frac{10 \mu\text{g}}{\text{L}} \right) \times \left(\frac{1 \text{ g}}{10^6 \mu\text{g}} \right) \times \left(\frac{1 \text{ lb}}{454 \text{ g}} \right) \times \left(\frac{3.785 \text{ L}}{\text{gal}} \right) \left(\frac{0.5 \times 10^6 \text{ gal}}{\text{day}} \right) \\ &= 0.04 \text{ lb/day of silver} \end{aligned}$$

The amount of silver discharged during each of the other three monitoring events was similarly determined to be:

0.05 lb/day; 0.02 lb/day, and 0.005 lb/day.

For the last data point the concentration of silver was reported by the laboratory to be less than the detection limit of 3 µg/L. For this calculation the detection limit was used to calculate the daily discharge, a conservative assumption.

The average daily discharge was calculated to be:

$$\left(\frac{0.04 + 0.05 + 0.02 + 0.005}{4} \right) \text{ lb/day} = 0.03 \text{ lb/day}$$

The plant operates 350 days/year (plant shuts down for two weeks in July).

The estimated annual discharge of silver is calculated as follows:

$$\text{Annual discharge} = (350 \text{ day/yr}) (0.03 \text{ lb/day}) = 10.5 \text{ lb of silver/yr}$$

Appendix C

GUIDANCE FOR REPORTING AQUEOUS AMMONIA

Year	Month	Day	Time	Location	Activity	Remarks
1947	1	1	10:00	San Francisco	Arrived	First day of trip
1947	1	2	10:00	San Francisco	Departed	Left for Los Angeles
1947	1	3	10:00	Los Angeles	Arrived	First day in LA
1947	1	4	10:00	Los Angeles	Departed	Left for San Diego
1947	1	5	10:00	San Diego	Arrived	First day in SD
1947	1	6	10:00	San Diego	Departed	Left for San Jose
1947	1	7	10:00	San Jose	Arrived	First day in SJ
1947	1	8	10:00	San Jose	Departed	Left for San Francisco
1947	1	9	10:00	San Francisco	Arrived	Second day in SF
1947	1	10	10:00	San Francisco	Departed	Left for Los Angeles
1947	1	11	10:00	Los Angeles	Arrived	Second day in LA
1947	1	12	10:00	Los Angeles	Departed	Left for San Diego
1947	1	13	10:00	San Diego	Arrived	Second day in SD
1947	1	14	10:00	San Diego	Departed	Left for San Jose
1947	1	15	10:00	San Jose	Arrived	Second day in SJ
1947	1	16	10:00	San Jose	Departed	Left for San Francisco
1947	1	17	10:00	San Francisco	Arrived	Third day in SF
1947	1	18	10:00	San Francisco	Departed	Left for Los Angeles
1947	1	19	10:00	Los Angeles	Arrived	Third day in LA
1947	1	20	10:00	Los Angeles	Departed	Left for San Diego
1947	1	21	10:00	San Diego	Arrived	Third day in SD
1947	1	22	10:00	San Diego	Departed	Left for San Jose
1947	1	23	10:00	San Jose	Arrived	Third day in SJ
1947	1	24	10:00	San Jose	Departed	Left for San Francisco
1947	1	25	10:00	San Francisco	Arrived	Fourth day in SF
1947	1	26	10:00	San Francisco	Departed	Left for Los Angeles
1947	1	27	10:00	Los Angeles	Arrived	Fourth day in LA
1947	1	28	10:00	Los Angeles	Departed	Left for San Diego
1947	1	29	10:00	San Diego	Arrived	Fourth day in SD
1947	1	30	10:00	San Diego	Departed	Left for San Jose
1947	1	31	10:00	San Jose	Arrived	Fourth day in SJ
1947	2	1	10:00	San Jose	Departed	Left for San Francisco
1947	2	2	10:00	San Francisco	Arrived	Fifth day in SF
1947	2	3	10:00	San Francisco	Departed	Left for Los Angeles
1947	2	4	10:00	Los Angeles	Arrived	Fifth day in LA
1947	2	5	10:00	Los Angeles	Departed	Left for San Diego
1947	2	6	10:00	San Diego	Arrived	Fifth day in SD
1947	2	7	10:00	San Diego	Departed	Left for San Jose
1947	2	8	10:00	San Jose	Arrived	Fifth day in SJ
1947	2	9	10:00	San Jose	Departed	Left for San Francisco
1947	2	10	10:00	San Francisco	Arrived	Sixth day in SF
1947	2	11	10:00	San Francisco	Departed	Left for Los Angeles
1947	2	12	10:00	Los Angeles	Arrived	Sixth day in LA
1947	2	13	10:00	Los Angeles	Departed	Left for San Diego
1947	2	14	10:00	San Diego	Arrived	Sixth day in SD
1947	2	15	10:00	San Diego	Departed	Left for San Jose
1947	2	16	10:00	San Jose	Arrived	Sixth day in SJ
1947	2	17	10:00	San Jose	Departed	Left for San Francisco
1947	2	18	10:00	San Francisco	Arrived	Seventh day in SF
1947	2	19	10:00	San Francisco	Departed	Left for Los Angeles
1947	2	20	10:00	Los Angeles	Arrived	Seventh day in LA
1947	2	21	10:00	Los Angeles	Departed	Left for San Diego
1947	2	22	10:00	San Diego	Arrived	Seventh day in SD
1947	2	23	10:00	San Diego	Departed	Left for San Jose
1947	2	24	10:00	San Jose	Arrived	Seventh day in SJ
1947	2	25	10:00	San Jose	Departed	Left for San Francisco
1947	2	26	10:00	San Francisco	Arrived	Eighth day in SF
1947	2	27	10:00	San Francisco	Departed	Left for Los Angeles
1947	2	28	10			

EMERGENCY PLANNING AND COMMUNITY RIGHT-TO-KNOW EPCRA Section 313 Guidance for Reporting Aqueous Ammonia

EPCRA Section 313 of the Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA) requires certain facilities manufacturing, processing, or otherwise using listed toxic chemicals to report their environmental releases of such chemicals annually. Beginning with the 1991 reporting year, such facilities also must report pollution prevention and recycling data for such chemicals, pursuant to section 6607 of the Pollution Prevention Act, 42 U.S.C. 13106. When enacted, EPCRA Section 313 established an initial list of toxic chemicals that was comprised of more than 300 chemicals and 20 chemical categories. EPCRA Section 313(d) authorizes EPA to add chemicals to or delete chemicals from the list, and sets forth criteria for these actions.

CONTENTS

Section 1.	Introduction	C-2
1.1	Who Must Report	C-2
1.2	Thresholds	C-2
1.3	Chemical Sources of Aqueous Ammonia	C-3
1.4	<i>De Minimis</i> Concentrations	C-3
Section 2.	Guidance for Reporting Aqueous Ammonia	C-4
2.1	Determining Threshold and Release Quantities for Ammonia	C-4
2.2	Chemical Sources of Aqueous Ammonia	C-5
2.2.1	Reporting Aqueous Ammonia Generated from Anhydrous Ammonia in Water	C-5
2.2.2	Reporting of Ammonia Generated from the Dissociation of Ammonium Salts (Other Than Ammonium Nitrate)	C-6
2.2.3	Reporting of Aqueous Ammonia Generated from the Dissociation of Ammonium Nitrate	C-7
Section 3.	CAS Number and List of Some Chemical Sources of Aqueous Ammonia ...	C-10

Section 1. Introduction

On June 30, 1995 EPA finalized four actions in response to a petition received in 1989 to delete ammonium sulfate (solution) from the list of toxic chemicals subject to reporting under EPCRA Section 313 of the Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA), 42 U.S.C. 11001. The four actions taken are summarized as follows: (1) deleted ammonium sulfate (solution) from the EPCRA Section 313 list of toxic chemicals, (2) required that threshold and release determinations for aqueous ammonia be based on 10 percent of the total aqueous ammonia present in aqueous solutions of ammonia, (3) modified the ammonia listing by adding the following qualifier: ammonia (includes anhydrous ammonia and aqueous ammonia from water dissociable ammonium salts and other sources; 10 percent of total aqueous ammonia is reportable under this listing), and (4) deleted ammonium nitrate (solution) as a separately listed chemical on the EPCRA Section 313 list of toxic chemicals. All actions are effective for the 1994 reporting year for reports due July 1, 1995, with the exception of the deletion of ammonium nitrate (solution) as a separately listed chemical, which is effective for the 1995 reporting year for reports due July 1, 1996. At the time that these actions were finalized, EPA indicated that the Agency would develop, as appropriate, interpretations and guidance that the Agency determines are necessary to facilitate accurate reporting for aqueous ammonia. This document constitutes such guidance for reporting under the ammonia listing.

Section 1.1 Who Must Report

A plant, factory, or other facility is subject to the provisions of EPCRA Section 313, if it meets all three of the following criteria:

- It conducts manufacturing operations (is included in Standard Industrial Classification (SIC) codes 20 through 39); and
- It has 10 or more full-time employees (or the equivalent 20,000 hours per year); and
- It manufactures, imports, processes, or otherwise uses any of the toxic chemicals listed on the EPCRA Section 313 list in amounts greater than the "threshold" quantities specified below.

Section 1.2 Thresholds

Thresholds are specified amounts of toxic chemicals used during the calendar year that trigger reporting requirements.

If a facility *manufactures* or *imports* any of the listed toxic chemicals, the threshold quantity will be:

- 25,000 pounds per toxic chemical or category over the calendar year.

If a facility *processes* any of the listed toxic chemicals, the threshold quantity will be:

- 25,000 pounds per toxic chemical or category over the calendar year.

If a facility *otherwise uses* any of the listed toxic chemicals (without incorporating it into any product or producing it at the facility), the threshold quantity is:

- 10,000 pounds per toxic chemical or category over the calendar year.

Section 1.3 Chemical Sources of Aqueous Ammonia

If a facility manufactures, processes, or otherwise uses anhydrous ammonia or aqueous ammonia, they must report under the ammonia listing. EPA is providing a table of Chemical Abstract Service (CAS) numbers and chemical names to aid the regulated community in determining whether they need to report under the ammonia listing for aqueous ammonia. This table includes a list of water dissociable ammonium salts which, when placed in water, are a source of aqueous ammonia. The table contains only commonly used ammonium salts and therefore is not exhaustive. If a facility manufactures, processes, or otherwise uses aqueous ammonia, regardless of its source, it must report under the ammonia listing, even if the source of the aqueous ammonia is not listed in the table provided in this document.

Section 1.4 *De Minimis* Concentrations

The ammonia listing is subject to the one percent *de minimis* concentration. Thus, solutions containing aqueous ammonia at a concentration in excess of *one percent of the 10 percent reportable under this listing* should be factored into threshold and release determinations.

Section 2. Guidance for Reporting Aqueous Ammonia

Note: for the purposes of reporting under the ammonia listing for aqueous ammonia, water dissociable ammonium salts means that the ammonium ion dissociates from its counterion when in solution.

Section 2.1 Determining Threshold and Release Quantities for Ammonia

If a facility manufactures, processes, or otherwise uses *anhydrous ammonia*, the quantity applied towards threshold determinations for the ammonia listing is the total quantity of the anhydrous ammonia manufactured, processed, or otherwise used. The quantity reported when calculating the amount of ammonia that is released, transferred, or otherwise managed is the total quantity of *anhydrous ammonia* released or transferred.

If the facility manufactures, processes, or otherwise uses *anhydrous ammonia* in quantities that exceed the appropriate threshold and subsequently dissolves some or all of the *anhydrous ammonia* in water, then the following applies: 1) threshold determinations are based on 100 percent of the *anhydrous ammonia* (simply 10 percent of *aqueous ammonia*); 2) release, transfer, and other waste management quantities for the *aqueous ammonia* are calculated as 10 percent of total ammonia; 3) release, transfer, and other waste management quantities for the *anhydrous ammonia* are calculated as 100 percent of the *anhydrous ammonia*.

If a facility manufactures, processes, or otherwise uses *aqueous ammonia*, the quantity applied toward threshold determinations for the ammonia listing is 10 percent of the total quantity of the *aqueous ammonia* manufactured, processed, or otherwise used. The quantity reported when calculating the amount of ammonia that is released, transferred, or otherwise managed is 10 percent of the total quantity of *aqueous ammonia* released or transferred.

If a facility dissolves a water dissociable ammonium salt in water that facility has manufactured *aqueous ammonia* and 10 percent of the total *aqueous ammonia* manufactured from these salts is to be included in manufacturing threshold determinations under the ammonia listing.

If *aqueous ammonia* from water dissociable ammonium salts is processed or otherwise used, then 10 percent of the total *aqueous ammonia* is to be included in all processing and otherwise use threshold determinations under the ammonia listing.

Example 1: In a calendar year, a facility places 25,000 lbs of anhydrous ammonia in water for processing and processes 25,000 lbs of aqueous ammonia from an ammonium salt. The facility must include all of the 25,000 lbs of anhydrous ammonia in the determination of the processing threshold, but only 10 percent (or 2,500 lbs) of the aqueous ammonia from the ammonium salt in the processing threshold determination.

Total aqueous ammonia is the sum of the two forms of ammonia (un-ionized, NH_3 , and ionized, NH_4^+) present in aqueous solutions. A precise calculation of the weight of total aqueous ammonia would require determining the ratio of the two forms of ammonia present using the pH and temperature of the solution. The weight of total aqueous ammonia can be more easily calculated by assuming that aqueous ammonia is comprised entirely of the NH_4^+ form or the NH_3 form. For the purpose of determining threshold and release quantities under EPCRA Section 313, EPA recommends that total aqueous ammonia be calculated in terms of NH_3 equivalents (i.e., for determining weights, assume total ammonia is comprised entirely of the NH_3 form). This method is simpler than using pH and temperature data to determine the ratio of the two forms present and is consistent with the presentation of total ammonia toxicity in a separate EPA document, *Ambient Water Quality Criteria for Ammonia* (EPA document #440/5-85-001, January 1985).

Section 2.2 Chemical Sources of Aqueous Ammonia

Aqueous ammonia may be generated in solution from a variety of sources that include the release of anhydrous ammonia to water and the dissociation of ammonium salts in water. Water dissociable ammonium salts are not reportable in their entirety under the ammonia listing; these salts are reportable to the extent that they dissociate in water, and only 10 percent of the total aqueous ammonia that results when these salts dissociate is reportable. If these salts are not placed in water, they are not reportable.

If these salts are purchased neat or as solids by a facility, then placed in water by that facility, the facility is *manufacturing* aqueous ammonia.

Section 2.2.1 Reporting Aqueous Ammonia Generated from Anhydrous Ammonia in Water

If the source of aqueous ammonia is anhydrous ammonia in water, total aqueous ammonia (calculated in terms of NH_3 equivalents) is equal to the quantity of anhydrous ammonia manufactured, processed, or otherwise used. A hypothetical scenario demonstrating the calculations involved in reporting aqueous ammonia generated from anhydrous ammonia in water is given in Example 2.

Example 2: In a calendar year, a facility uses 30,000 pounds of anhydrous ammonia to neutralize acids in a wastewater stream. The neutralized waste stream (containing aqueous ammonia from dissociated ammonium salts) is then transferred to a POTW. The quantity to be applied toward threshold determinations is the total quantity of anhydrous ammonia used in the waste stream neutralization, or 30,000 pounds. The quantity of ammonia reported as transferred is 10 percent of the total quantity of aqueous ammonia transferred, or 3,000 pounds.

Section 2.2.2 Reporting Aqueous Ammonia Generated from the Dissociation of Ammonium Salts (Other Than Ammonium Nitrate)

If the source of aqueous ammonia is the dissociation of ammonium salts in water, total aqueous ammonia (calculated in terms of NH_3 equivalents) is calculated from the weight

percent (wt%) of the NH_3 equivalents of the ammonium salt. The NH_3 equivalent wt% of an ammonium salt is calculated using the following equation:

$$\text{NH}_3 \text{ equivalent wt\%} = (\text{NH}_3 \text{ equivalent weight}) / (\text{MW ammonium salt}) \times 100$$

If the source of aqueous ammonia is a monovalent compound (such as ammonium chloride, NH_4Cl , ammonium nitrate, NH_4NO_3 , or ammonium bicarbonate (NH_4HCO_3), the NH_3 equivalent weight is equal to the MW of NH_3 (17.03 kg/kmol). If divalent compounds are involved (such as ammonium carbonate, $(\text{NH}_4)_2\text{CO}_3$), then the NH_3 equivalent weight is equal to the MW of NH_3 multiplied by two. Similarly, if trivalent compound are involved, then the NH_3 equivalent weight is equal to the MW of NH_3 multiplied by three.

Example 3:

The NH_3 equivalent wt% of ammonium chloride is calculated as follows:

$$\text{NH}_3 \text{ equivalent wt\%} = (\text{NH}_3 \text{ equivalent weight}) / (\text{MW ammonium chloride}) \times 100$$

$$\text{NH}_3 \text{ equivalent wt\%} = (17.03) / (53.49) \times 100$$

$$\text{NH}_3 \text{ equivalent wt\%} = 31.84\%$$

The NH_3 equivalent wt% of ammonium carbonate is calculated as follows:

$$\text{NH}_3 \text{ equivalent wt\%} = 2 \times (\text{NH}_3 \text{ equivalent weight}) / (\text{MW ammonium chloride}) \times 100$$

$$\text{NH}_3 \text{ equivalent wt\%} = 2 \times (17.03) / (96.09) \times 100$$

$$\text{NH}_3 \text{ equivalent wt\%} = 35.45\%$$

To aid the regulated community in reporting under the ammonia listing for aqueous ammonia, the table of chemical sources of aqueous ammonium provided in Section 3 of this document includes, in addition to CAS number, chemical name, and molecular weight, the NH_3 equivalent wt% of the commonly used, water dissociable ammonium salts listed in this table.

Example 4: In a calendar year, a facility uses 100,000 pounds of ammonium chloride, NH_4Cl , in aqueous solution which is released to wastewater streams, then transferred to a POTW. The NH_3 equivalent wt% of ammonium chloride is 31.84% (taken from Table 1 in Section 3 below or calculated as in Example 3 above). The total quantity of aqueous ammonia present in solution is 31.84% of the 100,000 pounds of ammonia chloride used, or 31,840 pounds. The quantity applied towards threshold determinations for the ammonia listing is 10 percent of the total quantity of aqueous ammonia present in solution, or 3,184 pounds. The quantity of ammonia reported as released or transferred is 10 percent of the total quantity of aqueous ammonia released or transferred, or 3,184 pounds.

Example 5: In a calendar year, a facility uses 500,000 pounds of ammonium carbonate, $(\text{NH}_4)_2\text{CO}_3$, and 400,000 pounds of ammonium bicarbonate, NH_4HCO_3 , in aqueous solution which is released to wastewater streams, then transferred to a POTW. The NH_3 equivalent wt% of ammonium carbonate is 35.45%, and the NH_3 equivalent wt% of ammonium bicarbonate is 21.54% (taken from Table 1 in Section 3 below or calculated as in Example 3 above). The quantity of aqueous ammonia present in solution from ammonium carbonate is 35.45% of the 500,000 pounds of ammonia carbonate used, or 177,250 pounds. The quantity of aqueous ammonia present in solution from ammonium bicarbonate is 21.54% of the 400,000 pounds of ammonia bicarbonate used or 86,160 pounds. The total quantity of aqueous ammonia present in solution is 263,410 pounds. The quantity applied towards threshold determinations for the ammonia listing is 10 percent of the total quantity of aqueous ammonia present in solution, or 26,341 pounds. The quantity of ammonia reported as released or transferred is 10 percent of the total quantity of aqueous ammonia released or transferred, or 26,341 pounds.

Section 2.2.3 Reporting Aqueous Ammonia Generated from the Dissociation of Ammonium Nitrate

Some sources of aqueous ammonia may be reportable under other EPCRA Section 313 category listings. Ammonium nitrate (solution) is relevant to reporting under the ammonia listing to the extent that 10 percent of the total aqueous ammonia that results when ammonium nitrate dissociates is reported when determining thresholds and calculating releases. However, under the nitrate compound category listing, ammonium nitrate (and other mixed salts containing ammonium and nitrate) must be reported in its entirety. When reporting ammonium nitrate under this category listing, the total nitrate compound, including both the nitrate ion portion and the ammonium counterion, is included when determining threshold quantities. However, only the nitrate ion portion is included when determining the amount of ammonium nitrate that is released, transferred, or otherwise managed in wastes. The calculations involved in determining threshold and release quantities for reporting under the nitrate compound category listing are described in a separate directive, *List of Toxic Chemicals within the Water Dissociable Nitrate Compounds Category and Guidance for Reporting* (EPA document #745-R-95-002, February 1995). Note: reporting ammonium nitrate under the ammonia listing and nitrate compounds category listing is effective for the 1995 reporting year for reports due July 1, 1996.

Example 6: In a calendar year, a facility uses 1,250,000 pounds of ammonium nitrate, NH_4NO_3 , in aqueous solution which is released to wastewater streams, then transferred to a POTW. The NH_3 equivalent wt% of ammonium nitrate is 21.28% (taken from Table 1 in Section 3 below or calculated as in Example 3 above). The total quantity of aqueous ammonia present in solution is 21.28% of the 1,250,000 pounds of ammonia chloride used, or 266,000 pounds. The quantity applied towards threshold determinations for the ammonia listing is 10 percent of the total quantity of aqueous ammonia present in solution, or 26,600 pounds. The quantity of ammonia reported as released or transferred is 10 percent of the total quantity of aqueous ammonia released or transferred, or 26,600 pounds. For determining thresholds and calculating releases under the nitrate compound category listing, see the separate directive, *List of Toxic Chemicals within the Water Dissociable Nitrate Compounds Category and Guidance for Reporting* (EPA document #745-R-95-002, February, 1995).

Example 7: In a calendar year, a facility transfers 100,000 pounds of nitric acid (HNO_3) to an on-site treatment facility. The nitric acid is neutralized with anhydrous ammonia, and treatment efficiency is 95 percent (the nitrate compound formed as a result of the treatment is ammonium nitrate, NH_4NO_3). The neutralized waste stream (containing aqueous ammonia from dissociated ammonium nitrate) is then transferred to a POTW. The quantity of nitric acid neutralized is 95 percent of 100,000 pounds or 95,000 pounds. The quantity of nitric acid neutralized is converted first to kilograms then to kilomoles using the following equations:

$$\begin{aligned}\text{Kilograms } \text{HNO}_3 \text{ neutralized} &= (\text{lbs } \text{HNO}_3 \text{ neutralized}) \times (0.4536 \text{ kg/lb}) \\ \text{Kilomoles } \text{HNO}_3 \text{ neutralized} &= (\text{kg } \text{HNO}_3) \div (\text{MW of } \text{HNO}_3 \text{ in kg/kmol})\end{aligned}$$

Substituting the appropriate values into the above equations yields:

$$\begin{aligned}\text{Kilograms } \text{HNO}_3 \text{ neutralized} &= 95,000 \text{ lbs} \times 0.4536 \text{ kg/lb} = 43,092 \text{ kg} \\ \text{Kilomoles } \text{HNO}_3 \text{ neutralized} &= 43,092 \text{ kg} \div 63.01 \text{ kg/kmol} = 683.9 \text{ kmol}\end{aligned}$$

The quantity of anhydrous ammonia used in kilomoles in the acid neutralization and the quantity of ammonium nitrate generated in kilomoles from the neutralization are equal to the quantity of nitric acid neutralized (683.9 kmol). The quantity of anhydrous ammonia used in kilograms and pounds in the acid neutralization is calculated as follows:

$$\begin{aligned}\text{Kilograms } \text{NH}_3 \text{ used} &= (\text{kmol } \text{NH}_3) \times (\text{MW of } \text{NH}_3 \text{ in kg/kmol}) \\ \text{Pounds } \text{NH}_3 \text{ used} &= (\text{kg } \text{NH}_3) \times (2.205 \text{ lbs/kg})\end{aligned}$$

Substituting the appropriate values into the above equation yields:

$$\begin{aligned}\text{Kilograms } \text{NH}_3 \text{ used} &= (683.9 \text{ kmol}) \times (17.03 \text{ kg/kmol}) = 11,647 \text{ kg} \\ \text{Pounds } \text{NH}_3 \text{ used} &= (11,647 \text{ kg}) \times (2.205 \text{ lbs/kg}) = 25,682 \text{ pounds}\end{aligned}$$

The quantity reported applied towards threshold determinations for the ammonia listing is the total quantity of anhydrous ammonia used in the acid neutralization, or 25,682 pounds. The quantity of ammonia reported as released or transferred is 10 percent of the total quantity of aqueous ammonia released or transferred, or 2,568 pounds. For determining thresholds and calculating releases under the nitrate compound category listing, see the separate directive, *List of Toxic Chemicals within the Water Dissociable Nitrate Compounds Category and Guidance for Reporting* (EPA document #745-R-95-002, February 1995).

Section 3. CAS Number and List of Some Chemical Sources of Aqueous Ammonia

EPA is providing the following table of CAS numbers and chemical names to aid the regulated community in determining whether they need to report under the ammonia listing for aqueous ammonia. If a facility manufactures, processes, or otherwise uses, *in aqueous solution*, a chemical which is listed below, they must report 10 percent of the total aqueous ammonia that is the result of the dissociation of this chemical. However, this list is not exhaustive. If a facility manufactures, processes, or otherwise uses, *in aqueous solution*, a water dissociable ammonium compound, they must report 10 percent of the total aqueous ammonia that is the result of the dissociation of the compound, even if the compound does not appear in the following table.

Table C-1
Listing by CAS Number and Molecular Weight of
Some Chemical Sources of Aqueous Ammonia

Chemical Name	Molecular Weight*	NH ₃ Equivalent Wt%	CAS Number
Ammonium acetate	77.08	22.09	631-61-8
Ammonium aluminum sulfate (Ammonium aluminum disulfate)	237.14	7.181	7784-25-0
Ammonium antimony fluoride (Diammonium pentafluoroantimonate)	252.82	13.47	32516-50-0
Ammonium arsenate (Ammonium arsenate, hydrogen) (Ammonium arsenate, dihydrogen)	158.97	10.71	13462-93-6
Ammonium arsenate (Diammonium arsenate) (Diammonium arsenate, hydrogen) (Diammonium arsenate, monohydrogen)	176.00	19.35	7784-44-3
Ammonium arsenite	124.96	13.63	13462-94-7
Ammonium azide	60.06	28.35	12164-94-2
Ammonium benzenesulfonate	175.20	9.720	19402-64-3
Ammonium benzoate	139.15	12.24	1863-63-4
Ammonium bromate	145.94	11.67	13843-59-9
Ammonium bromide	97.94	17.39	12124-97-9
Ammonium cadmium chloride (Ammonium cadmium trichloride)	236.81	7.191	18532-52-0
Ammonium carbamate	78.07	21.81	1111-78-0
Ammonium carbonate carbamate	157.13	21.68	8000-73-5
Ammonium carbonate (Diammonium carbonate)	96.09	35.45	506-87-3

Table C-1 (Continued)

Chemical Name	Molecular Weight*	NH ₃ Equivalent Wt%	CAS Number
Ammonium carbonate, hydrogen (Ammonium bicarbonate)	79.06	21.54	1066-33-7
Ammonium cerium nitrate (Ammonium hexanitratocerate) (Ammonium hexanitratocerate (IV)) (Diammonium cerium hexanitate)	548.23	6.213	16774-21-3
Ammonium cerous nitrate (Ammonium cerous nitrate, tetrahydrate)	486.22	7.005	13083-04-0
Ammonium chlorate	101.49	16.78	10192-29-7
Ammonium perchlorate	117.49	14.49	7790-98-9
Ammonium chloride	53.49	31.84	12125-02-9
Ammonium chromate (Ammonium chromate (VI)) (Diammonium chromate)	152.07	22.40	7788-98-9
Ammonium chromate (Ammonium dichromate) (Ammonium dichromate (VI)) (Ammonium bichromate) (Diammonium dichromate)	252.06	13.51	7789-09-5
Ammonium chromium sulfate (Ammonium chromic sulfate)	265.17	6.422	13548-43-1
Ammonium citrate (Ammonium citrate, monohydrogen) (Ammonium citrate, dibasic) (Diammonium citrate) (Diammonium citrate, hydrogen)	226.19	15.06	3012-65-5
Ammonium citrate (Ammonium citrate, tribasic) (Triammonium citrate)	243.22	21.01	3458-72-8
Ammonium cobalt sulfate (Ammonium cobaltous sulfate)	289.14	11.78	13596-46-8
Ammonium cupric chloride (Ammonium chlorocuprate (II)) (Diammonium copper tetrachloride) (Diammonium tetrachlorocuprate)	241.43	14.11	15610-76-1
Ammonium cyanate (Ammonium isocyanate)	60.06	28.35	22981-32-4
Ammonium cyanide	44.06	38.65	12211-52-8
Ammonium cyanoaurate, monohydrate (Ammonium tetracyanoaurate, monohydrate)	319.07	5.337	14323-26-3

Table C-1 (Continued)

Chemical Name	Molecular Weight*	NH ₃ Equivalent Wt%	CAS Number
Ammonium cyanoaurate (Ammonium dicyanoaurate)	267.04	6.377	31096-40-9
Ammonium ferricyanide (Ammonium hexacyanoferrate (III)) (Triammonium hexacyanoferrate)	266.07	19.20	14221-48-8
Ammonium ferrocyanide (Ammonium hexacyanoferrate (II)) (Tetraammonium ferrocyanide) (Tetraammonium hexacyanoferrate)	284.11	23.98	14481-29-9
Ammonium fluoride	37.04	45.98	12125-01-8
Ammonium fluoride (Ammonium difluoride) (Ammonium bifluoride) (Ammonium fluoride, hydrogen) (Ammonium difluoride, hydrogen) (Ammonium bifluoride, hydrogen)	57.04	29.86	1341-49-7
Ammonium fluoroborate (Ammonium tetrafluoroborate)	104.84	16.24	13826-83-0
Ammonium fluorogermanate (IV) (Ammonium hexafluorogermanate (IV)) (Diammonium hexafluorogermanate)	222.66	15.30	16962-47-3
Ammonium fluorophosphate (Ammonium hexafluorophosphate)	163.00	10.45	16941-11-0
Ammonium fluorosulfate (Ammonium fluorosulfonate)	117.10	14.54	13446-08-7
Ammonium formate	63.06	27.01	540-69-2
Ammonium gallium sulfate	282.90	6.020	15335-98-5
Ammonium hydroxide	35.05	48.59	1336-21-6
Ammonium iodide	144.94	11.75	12027-06-4
Ammonium iridium chloride (Ammonium chloroiridate (III)) (Ammonium hexachloroiridate) (Triammonium hexachloroiridate)	459.05	11.13	15752-05-3
Ammonium iron sulfate (Ammonium ferric sulfate) (Ammonium iron disulfate)	269.02	6.330	10138-04-2
Ammonium iron sulfate (Ammonium ferrous sulfate) (Diammonium iron disulfate) (Diammonium ferrous disulfate)	286.05	11.91	10045-89-3

Table C-1 (Continued)

Chemical Name	Molecular Weight*	NH ₃ Equivalent Wt%	CAS Number
Ammonium lactate (Ammonium 2-hydroxypropionate)	107.11	15.90	515-98-0
Ammonium laurate (Ammonium dodecanoate)	217.35	7.835	2437-23-2
Ammonium magnesium sulfate	252.50	13.49	14727-95-8
Ammonium malate	168.15	20.26	6283-27-8
Ammonium malate, hydrogen (Ammonium bimalate)	151.12	11.27	5972-71-4
Ammonium molybdate (Diammonium molybdate)	196.01	17.38	13106-76-8
Ammonium molybdate (Ammonium heptamolybdate) (Ammonium molybdate, hydrate) (Ammonium molybdate, tetrahydrate) (Ammonium <i>paramolybdate</i> , tetrahydrate)	1,163.8	8.780	12054-85-2
Ammonium nickel chloride, hexahydrate	183.09	9.301	16122-03-5
Ammonium nickel sulfate (Ammonium nickel sulfate, hexahydrate) (Ammonium nickel disulfate, hexahydrate) (Diammonium nickel disulfate, hexahydrate)	286.88	11.87	7785-20-8
Ammonium nitrate	80.04	21.28	6484-52-2
Ammonium nitrate sulfate	212.18	24.08	12436-94-1
Ammonium nitrite	64.04	26.59	13446-48-5
Ammonium oleate	299.50	5.686	544-60-5
Ammonium oxalate	124.10	27.45	1113-38-8
Ammonium palladium chloride (Ammonium chloropalladate (II)) (Ammonium tetrachloropalladate (II)) (Diammonium tetrachloropalladate)	284.31	11.98	13820-40-1
Ammonium phosphate (Ammonium orthophosphate)	149.09	34.27	10124-31-9
Ammonium phosphate (Ammonium biphosphate) (Ammonium phosphate, hydrogen) (Ammonium phosphate, dihydrogen) (Ammonium orthophosphate, dihydrogen) (Ammonium phosphate, monobasic)	115.03	14.80	7722-76-1

Table C-1 (Continued)

Chemical Name	Molecular Weight*	NH ₃ Equivalent Wt%	CAS Number
Ammonium phosphate (Ammonium phosphate, hydrogen) (Ammonium orthophosphate, monohydrogen) (Ammonium phosphate, dibasic) (Ammonium orthophosphate, dibasic) (Diammonium phosphate) (Diammonium orthophosphate) (Diammonium phosphate, hydrogen) (Diammonium phosphate, monohydrogen) (Diammonium orthophosphate, hydrogen)	132.06	25.79	7783-28-0
Ammonium phosphinate (Ammonium hypophosphite)	83.03	20.51	7803-65-8
Ammonium phosphite (Ammonium biphosphite) (Ammonium phosphite, dihydrogen)	99.03	17.20	13446-12-3
Ammonium picramate	216.15	7.879	1134-85-6
Ammonium propionate	91.11	18.69	17496-08-1
Ammonium rhodium chloride (Ammonium chlororhodate (III)) (Ammonium hexachlororhodate (III)) (Triammonium rhodium hexachloride) (Triammonium hexachlororhodate)	369.74	13.82	15336-18-2
Ammonium salicylate (Ammonium 2-hydroxybenzoate)	155.15	10.98	528-94-9
Ammonium selenide	115.04	29.61	66455-76-3
Ammonium silicon fluoride (Ammonium fluorosilicate) (Ammonium hexafluorosilicate) (Diammonium silicon hexafluoride) (Diammonium fluorosilicate) (Diammonium hexafluorosilicate)	178.15	19.12	16919-19-0
Ammonium stearate (Ammonium octadecanoate)	301.51	5.648	1002-89-7
Ammonium succinate (Diammonium succinate)	152.15	22.39	2226-88-2
Ammonium sulfamate (Ammonium amidosulfate) (Ammonium amidosulfonate)	114.12	14.92	7773-06-0
Ammonium sulfate (Diammonium sulfate)	132.13	25.78	7783-20-2

Table C-1 (Continued)

Chemical Name	Molecular Weight*	NH₃ Equivalent Wt%	CAS Number
Ammonium sulfate (Ammonium bisulfate) (Ammonium sulfate, hydrogen) (Ammonium sulfate, monohydrogen)	115.10	14.80	7803-63-6
Ammonium persulfate (Ammonium peroxydisulfate) (Ammonium peroxydisulfate) (Diammonium persulfate) (Diammonium peroxydisulfate)	228.19	14.93	7727-54-0
Ammonium sulfide (Ammonium bisulfide) (Ammonium sulfide, hydrogen)	51.11	33.32	12124-99-1
Ammonium sulfide (Ammonium monosulfide) (Diammonium sulfide)	68.14	49.99	12135-76-1
Ammonium sulfide (Diammonium pentasulfide)	196.39	17.34	12135-77-2
Ammonium sulfite, monohydrate (Diammonium sulfite, monohydrate)	116.13	29.33	7783-11-1
Ammonium sulfite (Ammonium bisulfite) (Ammonium sulfite, hydrogen)	99.10	17.18	10192-30-0
Ammonium tetrachloroaurate (III), hydrate	356.82	4.772	13874-04-9
Ammonium thiocarbamate	94.13	18.09	16687-42-6
Ammonium thiocarbonate (Diammonium trithiocarbonate)	144.27	23.61	13453-08-2
Ammonium thiocyanate (Ammonium isothiocyanate) (Ammonium sulfocyanate) (Ammonium rhodanate) (Rhodanid)	76.12	22.37	1762-95-4
Ammonium dithionate	196.19	17.36	60816-52-6
Ammonium thiosulfate (Ammonium hyposulfite) (Diammonium thiosulfate)	148.20	22.98	7783-18-8
Ammonium tin bromide (Ammonium bromostannate (IV)) (Ammonium hexabromostannate (IV)) (Diammonium hexabromostannate)	634.19	5.371	16925-34-1

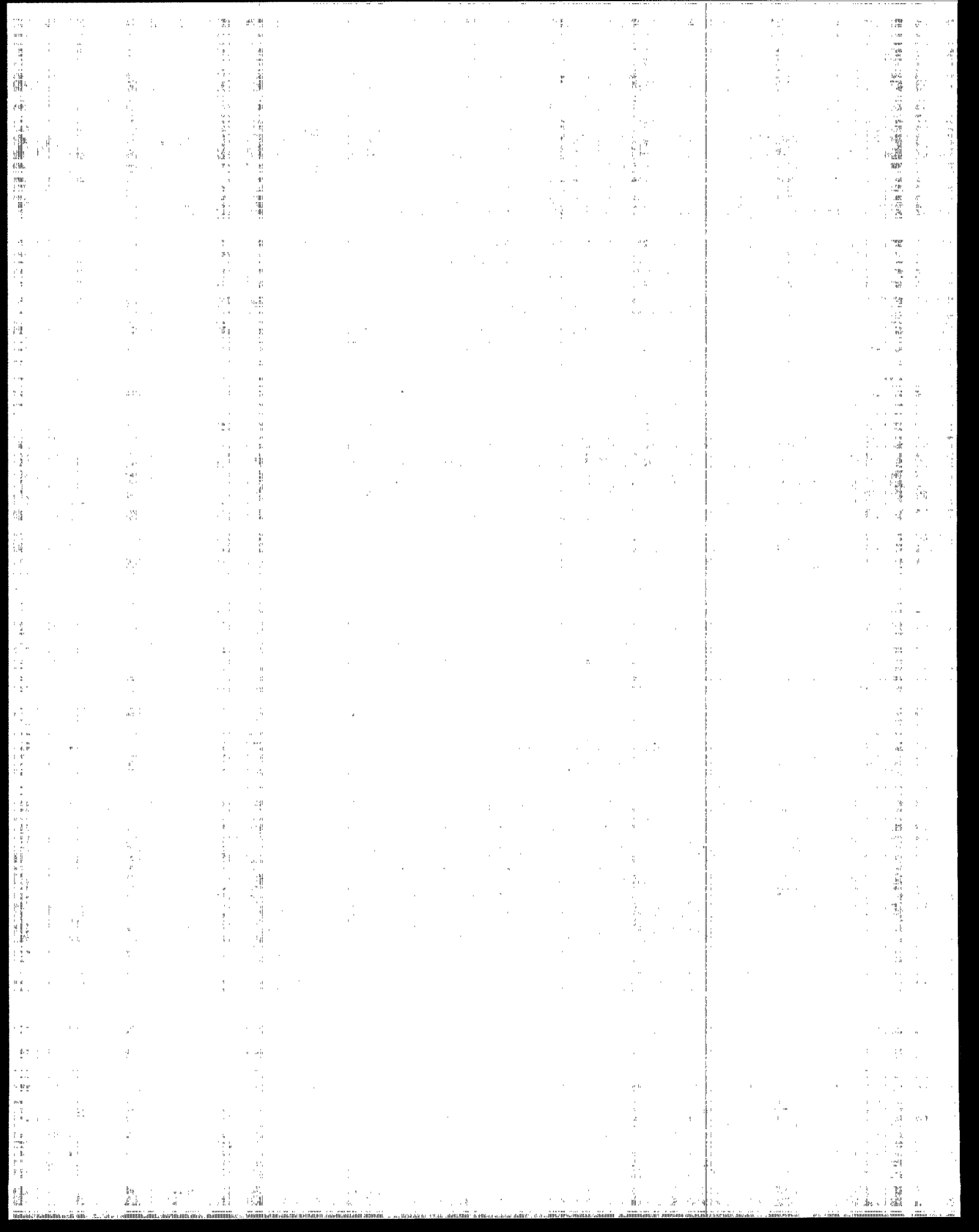
Table C-1 (Continued)

Chemical Name	Molecular Weight*	NH ₃ Equivalent Wt%	CAS Number
Ammonium tin chloride (Ammonium chlorostannate (IV)) (Ammonium hexachlorostannate (IV)) (Diammonium tin hexachloride) (Diammonium hexachlorostannate)	367.48	9.269	16960-53-5
Ammonium titanium fluoride (Ammonium fluorotitanate (IV)) (Ammonium hexafluorotitanate (IV)) (Diammonium titanium hexafluoride) (Diammonium hexafluorotitanate)	197.95	17.21	16962-40-6
Ammonium titanium oxalate, monohydrate (Diammonium dioxalatoxotitanate, monohydrate)	276.00	12.34	10580-03-7
Ammonium tungstate (Ammonium tungstate (VI)) (Ammonium <i>paratungstate</i>) (Hexaammonium tungstate)	1,779.2	5.743	12028-06-7
Ammonium tungstate (Ammonium tungstate (VI)) (Ammonium <i>paratungstate</i>) (Decaammonium tungstate)	3,058.6	5.568	11120-25-5
Ammonium valerate (Ammonium pentoate)	119.16	14.29	42739-38-8
Ammonium zinc chloride (Ammonium chlorozincate) (Ammonium tetrachlorozincate) (Diammonium tetrachlorozincate)	243.27	14.00	14639-97-5

*For hydrated compounds, e.g., ammonium sulfite, monohydrate, the molecular weight excludes the weight of the hydrate portion.

Appendix D

GUIDANCE FOR REPORTING SULFURIC ACID





**EMERGENCY PLANNING AND
COMMUNITY RIGHT-TO-KNOW
EPCRA Section 313**

**Guidance for Reporting Sulfuric Acid (acid aerosols including mists,
vapors, gas, fog, and other airborne forms of any particle size)**

Section 313 of the Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA) requires certain facilities manufacturing, processing, or otherwise using listed toxic chemicals to report their environmental releases of such chemicals annually. Beginning with the 1991 reporting year, such facilities also must report pollution prevention and recycling data for such chemicals, pursuant to section 6607 of the Pollution Prevention Act, 42 U.S.C. 13106. When enacted, EPCRA Section 313 established an initial list of toxic chemicals that was comprised of more than 300 chemicals and 20 chemical categories. EPCRA section 313(d) authorizes EPA to add chemicals to or delete chemicals from the list, and sets forth criteria for these actions.

CONTENTS

Section	1.0	Introduction	D-3
	1.1	Who Must Report	D-3
	1.2	Thresholds	D-4
	1.3	What Constitutes Aerosol Forms of Sulfuric Acid and Their Manufacture, Processing, or Otherwise Use	D-4
Section	2.0	Guidance on Sulfuric Acid Aerosols For Certain Specific Activities That Generate Aerosols Forms	D-5
	2.1	Sulfuric Acid Aerosols Generated in Acid Reuse Systems ..	D-5
	2.2	Sulfuric Acid Aerosols Removed By Scrubbers	D-6
	2.3	Sulfuric Acid Aerosols Generated In Storage Tanks	D-6
Section	3.0	Sulfuric Acid and Its Formation in Air	D-6
	3.1	Industrial Sources of Sulfuric Acid Aerosols	D-7
	3.1.1	Pulp and Paper Mills	D-9
	3.1.2	Acid Aerosols From Sulfuric Acid Manufacture	D-10
	3.1.3	Smelters	D-13
	3.1.4	Petroleum Refining	D-13

3.1.5	Sulfuric Acid Aerosol Formation In Stacks From Combustion Processes	D-13
3.1.6	Coal Combustion	D-15
3.1.7	Fuel Oil Combustion	D-15

Section 4.0	Measurement Methods	D-16
-------------	---------------------------	------

References	D-16
------------------	------

Appendix 1	D-19
------------------	------

Section 1.0. Introduction

On June 30, 1995 (60 FR 34182), EPA modified the listing for sulfuric acid (Chemical Abstracts Service Number 7664-93-9) on the list of toxic chemicals subject to the reporting requirements under section 313 of the Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA) (5). EPA modified the listing by deleting non-aerosol forms of sulfuric acid from the section 313 list based on the conclusion that they cannot reasonably be anticipated to cause adverse effects on human health or the environment. EPA added a modifier to the listing for sulfuric acid to exclude the non-aerosol forms. The listing now reads "Sulfuric acid (acid aerosols including mists, vapors, gas, fog, and other airborne forms of any particle size)." Therefore, beginning with the 1994 reporting year, facilities are no longer required to include non-aerosol forms of sulfuric acid in threshold and release determinations. In this document we will use the term "sulfuric acid aerosols" to indicate airborne forms of sulfuric acid as listed in section 313 of EPCRA.

The purpose of this document is to assist facilities in determining the sources and amounts of sulfuric acid aerosols that are to be included in threshold and release determinations under EPCRA section 313. This document is not meant to be exhaustive, but rather provide some guidance to help facilities in their determination of threshold and release quantities. Threshold and release determinations for sulfuric acid aerosols are highly dependent on site specific conditions and equipment. Therefore, this document can only provide general information concerning the possible formation and release of sulfuric acid aerosols.

Section 1.1. Who Must Report

A plant, factory, or other facility is subject to the provisions of EPCRA section 313, if it meets all three of the following criteria:

- It is included in the primary Standard Industrial Classification (SIC) codes 20 through 39 and beginning January 1, 1998, it is in one of the following industries: Metal Mining, SIC code 10 (except SIC codes 1011, 1081, and 1094); Coal Mining, SIC code 12 (except SIC code 1241); Electric Utilities, SIC codes 4911, 4931, or 4939 (each limited to facilities that combust coal and/or oil for the purpose of generating power for distribution in commerce); Commercial Hazardous Waste Treatment, SIC code 4953 (limited to facilities regulated under the Resource Conservation and Recovery Act, subtitle C, 42 U.S.C. section 6921 *et seq.*); Chemicals and Allied Products-Wholesale, SIC code 5169; Petroleum Bulk Terminals and Plants, SIC code 5171; and, Solvent Recovery Services, SIC code 7389 (limited to facilities primarily engaged in solvent recovery services on a contract or fee basis); and
- It has 10 or more full-time employees (or the equivalent of 20,000 hours per year); and
- It manufactures (includes imports), processes or otherwise uses any of the toxic chemicals listed on the EPCRA section 313 list in amounts greater than the threshold quantities specified below.

In addition, pursuant to Executive Order 12856 entitled "Federal Compliance with Right-to-Know Laws and Pollutant Prevention Requirements," federal facilities are required to comply with the reporting requirements of EPCRA Section 313 beginning with calendar year 1994. This requirement is mandated regardless of the facility's SIC code.

Section 1.2. Thresholds

Thresholds are specified amounts of toxic chemicals manufactured, processed, or otherwise used during the calendar year that trigger reporting requirements. Reporting is required for sulfuric acid aerosols if the following thresholds are exceeded.

- If a facility *manufactures or imports* 25,000 pounds of sulfuric acid aerosols over the calendar year.
- If a facility *processes* 25,000 pounds of sulfuric acid aerosols over the calendar year.
- If a facility *otherwise uses* 10,000 pounds of sulfuric acid aerosols over the calendar year.

The quantities of sulfuric acid aerosols included in threshold determinations are not limited to the amounts of sulfuric acid aerosols released to the environment. All sulfuric acid aerosols manufactured, processed, or otherwise used are to be counted toward threshold determinations. This includes any amount of sulfuric acid aerosols that may be generated in closed systems or that are generated in stacks prior to or after being treated by scrubbers.

Section 1.3. What Constitutes Aerosol Forms of Sulfuric Acid and Their Manufacture, Processing, or Otherwise Use

For the purposes of the reporting requirements under EPCRA section 313, sulfuric acid aerosols include mists, vapors, gas, fog, and other airborne forms of any particle size. Note that there is no size limit for particles that must be included under the EPCRA section 313 sulfuric acid aerosols listing. Although the qualifier includes the terms mists, vapors, gas, and fog these terms are not specifically defined for EPCRA section 313 since the last part of the qualifier "other airborne forms of any particle size" makes it clear that any airborne form is covered by the listing. The specific terms mists, vapors, gas, and fog are included to make it clear that sulfuric acid that is identified as being in one of these forms would be covered by the sulfuric acid aerosols listing.

If sulfuric acid is present in the form of a gas, fog, vapor, or mist or any other airborne form then sulfuric acid is considered to be in the aerosol form and is covered by the EPCRA section 313 sulfuric acid aerosols listing. Solutions of sulfuric acid which do not become airborne are not covered by the EPCRA section 313 sulfuric acid aerosols listing but such solutions may generate sulfuric acid aerosols during their manufacture, processing or otherwise use. In general, sulfuric acid aerosols are manufactured any time a solution of sulfuric acid is made to become airborne such as when it is sprayed or distilled. If the generation of sulfuric acid aerosols through spraying or other means is intentional (i.e., it is intended that the sulfuric acid aerosol be generated for a particular use activity) then, in addition to manufacturing the sulfuric acid aerosol, such aerosols are also being otherwise used. Thus, spraying of sulfuric acid aerosols

on to an item for cleaning, etching, or other purposes constitutes the manufacture and otherwise use of sulfuric acid aerosols. If sulfuric acid aerosols are used in a process in which any part of the sulfuric acid becomes incorporated into a product which is then distributed in commerce then, under EPCRA section 313, the sulfuric acid aerosols are considered to have been processed.

Section 2.0. Guidance On Sulfuric Acid Aerosols For Certain Specific Activities That Generate Aerosols Forms

EPA has provided the following guidance for specific activities that generated sulfuric acid aerosols. The guidance in sections 2.1, 2.2, and 2.3 is intended to apply only to the specific situations discussed in these sections. If you are not sure whether this guidance applies to the situation at your facility, then EPA should be consulted before using this guidance.

Section 2.1. Sulfuric Acid Aerosols Generated In Acid Reuse Systems

When solutions of sulfuric acid are aerosolized the "manufacture" of a listed chemical (sulfuric acid aerosols) has occurred. This is a result of the qualifier to the sulfuric acid listing, which excludes non-aerosol forms and limits the reporting to aerosol forms only. The addition of the acid aerosol qualifier has an impact on certain processes that, prior to the addition of the qualifier, would not have been considered to be "manufacturing" a listed chemical. Acid reuse systems that use aqueous solutions of sulfuric acid to generate acid aerosols, use the acid aerosols, condense them back into solution, and then reuse the acid solution again and again are impacted by the addition of the acid aerosol qualifier. In such processes, the continuous reuse of the acid solutions generates very large quantities of acid aerosols that technically should be counted towards the "manufacture" [the generation of the acid aerosol is the "manufacture" of sulfuric acid (acid aerosol)] and "otherwise use" thresholds. This may result in many facilities greatly exceeding the "manufacture" and "otherwise use" reporting thresholds that, prior to the addition of the qualifier, would not have exceeded thresholds.

While it is technically correct to apply all of the quantities of acid aerosols generated in such systems towards the "manufacture" and "otherwise use" reporting thresholds, EPA did not intend to increase the reporting burden as a result of addition of the sulfuric acid aerosol qualifier. In addition, under EPA's general approach to reuse systems, a toxic chemical is not counted toward thresholds each time it is reused but only once per reporting period, and that approach would apply to sulfuric acid reuse systems were it not for the aerosol qualifier. Therefore, EPA is providing the following guidance to reduce the reporting burden for facilities that operate such processes and to bring the treatment of such systems into alignment with EPA's general approach to reuse.

Rather than having facilities count all quantities of acid aerosol generated in such systems towards the "manufacture" and "otherwise use" thresholds, EPA will allow facilities to apply the total volume of acid in these systems only once to these thresholds. For example, if an acid reuse system starts the year with 2000 pounds of acid and 500 pounds is added during the year then the total amount applied towards acid aerosol thresholds would be 2500 pounds. This reflects a one time per year counting of all of the acid molecules as being in the acid aerosol form rather than counting them over and over again each time the acid aerosol form is generated and subsequently used. Since in these acid reuse systems the acid aerosols are "manufactured" and then

"otherwise used" the 10,000 pound "otherwise use" threshold would be the threshold that would first trigger reporting from such systems.

This guidance applies only to acid reuse systems and the reporting of sulfuric acid aerosols under EPCRA section 313. This guidance does not apply to any other types of processes or to any other listed chemical.

2.2. Sulfuric Acid Aerosols Removed By Scrubbers

When a scrubber is used to remove sulfuric acid aerosols prior to or in a stack, the acid aerosols are usually converted to the non-aerosol form. The non-aerosol forms of sulfuric acid are not reportable under EPCRA section 313 because the qualifier to the sulfuric acid listing includes only acid aerosol forms. Sulfuric acid as a discrete chemical has not actually been destroyed by the scrubber, but the form of sulfuric acid reportable under EPCRA section 313 has been destroyed. Therefore, since sulfuric acid aerosols removed by scrubbers are converted to a non-reportable form, the quantity removed by the scrubber can be reported as having been treated for destruction.

2.3. Sulfuric Acid Aerosols Generated In Storage Tanks

Sulfuric acid aerosols are generated in the empty space (head space) above sulfuric acid solutions contained in storage tanks. The amounts of acid aerosols generated in such storage tanks are to be applied towards the "manufacture" threshold for sulfuric acid aerosols. In such storage tanks the sulfuric acid molecules are constantly moving between the atmosphere and the solution. EPA does not intend for facilities to count such movement of the acid molecules in and out of the stored acid solution as continuous "manufacture" of sulfuric acid aerosols. For such storage tanks the amount of acid aerosol to be applied towards the "manufacture" threshold is the average amount that existed in the atmosphere above the acid solution during the year.

Each facility should determine the average conditions for their specific storage tank (i.e., the capacity of the tank, the average amount in the tank, the average head space in the tank, the concentration of the acid solution stored, the temperature, and other information that may have an impact on aerosol calculations) and make the appropriate calculation of the amount of acid aerosol to apply towards the "manufacture" threshold. Any amounts of sulfuric acid aerosols that may be released from the storage tank through venting or fugitive releases must also be included in the threshold determination. If the storage tank is refilled and drawn down several times during the year then the calculations should be based on all of the acid that was stored in the tank. For example, if a 10,000 pound capacity tank is refilled and drawn down 6 times during the year (such that 60,000 pounds of acid were stored in the tank during the year) then the tank calculations, based on the average condition for one 10,000 pound tank of acid, should be multiplied by 6.

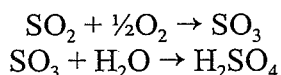
Section 3.0. Sulfuric Acid And Its Formation In Air

Sulfuric acid (H_2SO_4) is miscible in water in all proportions and has a strong attraction for water. The anhydrous chemical boils at 279.6°C (1). Commercial sulfuric acid normally contains 93 to 98% sulfuric acid with the remainder being water. A boiling point-composition diagram

(Figure 1, Appendix 1) for aqueous sulfuric acid, indicates that below 75% H₂SO₄, the vapor evaporating from a solution of the acid is essentially water. This fact is illustrated in Table 1a of Appendix 1, which contains the partial pressure of sulfuric acid and total vapor pressure of the solution over aqueous sulfuric acid solutions at various concentrations (1). Since the partial pressure of concentrated sulfuric acid is very low, little sulfuric acid is expected to volatilize from sulfuric acid solutions such as may be present in storage tanks. However, as discussed above, the amount of acid aerosols generated is dependent on the quantity of acid in the tank(s) during the year, the concentration, temperature, and other factors. The information in Appendix 1 and the guidance in section 2.3 can be used to assist in determining if significant amounts of sulfuric acid aerosols are present in storage tanks.

Sulfuric acid containing dissolved sulfur trioxide (SO₃) is known as oleum, fuming sulfuric acid or disulfuric acid. The vapor pressure of sulfuric acid over oleum containing 10% to 30% of free SO₃ by weight is shown in Table 2a of Appendix 1 (2). Since the vapor pressure of sulfur trioxide over oleum is high, sulfuric acid aerosols also form when oleum is exposed to air containing moisture.

Sulfuric acid is generally formed by the oxidation of sulfur dioxide (SO₂) and the reaction of the resulting sulfur trioxide (SO₃) with water.



While thermodynamically, SO₂ has a strong tendency to react with oxygen to form SO₃; under normal tropospheric (lower atmosphere) conditions the reaction rate is very slow in the gas phase (3, 17, 18, 19). Other than within a reaction chamber, SO₂ is unlikely to generate SO₃ and then sulfuric acid. However, once SO₃ is formed, it is converted to H₂SO₄ so rapidly (within milliseconds) at normal humidities, that any reaction in which SO is formed in moist air is equivalent to forming H₂SO₄ (3,18). In stacks from combustion processes, moisture in the **stack** would be expected to convert any SO₃ present into sulfuric acid aerosols. This being the case, the quantity of SO generated in such stacks (multiplied by 98.08/80.07, the molecular weight of sulfuric acid divided by the molecular weight of sulfur trioxide) should be included with those of H₂SO₄. If SO₃ is produced within a stack or unit of the plant without moisture present, sulfuric acid aerosols would not be produced. Although the SO₃ releases may be converted to H₂SO₄ in the environment, facilities are not responsible for conversions that may take place in the environment after a chemical that is not listed under EPCRA section 313, such as SO₃, has been released. Therefore, if SO₃ is the chemical that is released from the facility, the facility is not required to include it, or any H₂SO₄ produced in the environment from the released SO₃, in any EPCRA section 313 calculations of thresholds or releases.

Section 3.1. Industrial Sources Of Sulfuric Acid Aerosols

It is clear that industries required to report *sulfuric acid aerosol* releases will be among those that had previously reported *sulfuric acid* releases to air under EPCRA section 313. Facilities that previously reported over 25,000 pounds of sulfuric acid releases to air have exceeded the manufacturing threshold quantity of sulfuric acid aerosols necessary for reporting under the new listing. Additional facilities may be required to report because releases of sulfuric

acid to air would not have included, for example, amounts of sulfuric acid aerosols that were produced in the stack and subsequently removed by scrubbers or produced internally during sulfuric acid manufacturing, processing, or use and that were removed by scrubbers prior to the stack. Since these amounts of sulfuric acid aerosols do count towards the EPCRA section 313 threshold determinations, facilities with less than 25,000 pounds of air releases are not excluded from reporting. In addition, some facilities may be using sulfuric acid aerosols in excess of 10,000 pounds and would also be required to report. According to the 1993 Toxics Release Inventory (TRI), there were 191 facilities reporting releases of 25,000 pounds or more of sulfuric acid to air. The number of these facilities in each of 2-digit standard industrial categories (SIC) is shown in Table 1, as well as the prominent types of industries within the category that have reported sulfuric acid emissions to air. The industries shown in italics include 34 facilities that are in the 80th percentile (over 178,000 pounds per year) for sulfuric acid releases to air. These 34 facilities' air emissions are almost entirely from point sources, suggesting that either sulfuric acid is formed in the stack from sulfur trioxide or sulfuric acid is aerosolized in a process that leads to its release in the stack. Thirty two of these sites reported producing the sulfuric acid; the copper smelters and phosphate fertilizer plants produced sulfuric acid for sale or distribution.

Table 1. Industrial Categories of Facilities Emitting over 25,000 lbs/yr of Sulfuric Acid Aerosols in 1993

Category (SIC Code)	No. Sites*	Major Industries**
Paper and Allied Products (26)	185	<i>Pulp, paper and paperboard mills.</i>
Chemicals and Allied Products (28)	53	<i>Phosphate fertilizers; Industrial inorganic chemicals.</i>
Primary metal industries (33)	23	<i>Copper smelting; Blast furnaces and steel mills</i>
Food and Kindred Products (20)	11	<i>Wet corn milling; fats and oils; liquors; malt beverages.</i>
Lumber, Wood Products (24)	8	Sawmills; Reconstituted wood products
Stone, clay, glass, concrete (32)	6	<i>Glass</i>
Petroleum refining (29)	4	<i>Petroleum refining</i>
Metal Products, except machinery (34)	4	Metal coatings
Tobacco Manufacturers (21)	1	Tobacco stemming and redrying

*A site may list more than one SIC code.

** The industries shown in italics include facilities that are in the 80th percentile for sulfuric acid releases to air.

The industrial breakdown does not necessarily indicate that emissions result from processes unique to the industry. For example, phosphate fertilizer manufacturers, which use sulfuric acid to make phosphoric acid and normal superphosphate, may produce their own sulfuric acid from elemental sulfur and may also use it captively. Sulfuric acid emissions from phosphate fertilizer manufacturing may therefore be primarily from sulfuric acid manufacturing. Similarly, sulfuric acid is a known component in flue gas from fossil fuel combustion and waste incineration. The $\text{SO}_3/\text{H}_2\text{SO}_4$ (SO_3 , as stated previously is immediately transformed into sulfuric acid in the presence of water) produced from combustion sources is between 1 and 3% of the SO_x emitted by these sources (the rest being SO_2). It is not clear why sulfuric acid is emitted from

combustion sources. A possible explanation is that there are substances in the flue gas or on the stack walls that catalyze the oxidation of sulfur dioxide to sulfur trioxide, similar to the heterogeneous reactions that can occur in the atmosphere (17-19). Sulfuric acid is also formed in some flue desulfurization processes (7).

Section 3.1.1 Pulp and Paper Mills

The kraft pulping process involves the digesting of wood chips at elevated temperature in "white liquor", an aqueous solution of sodium sulfide and sodium hydroxide, to dissolve the lignin that binds the cellulose fibers of the wood together. The spent liquor used to digest wood chips, called "black liquor", is combusted in recovery furnaces to recover heat and cooking chemicals. Sulfuric acid is present in flue gas from kraft recovery furnaces and has been cited as being one of the five most prevalent air toxics released from recovery furnaces of the direct contact evaporator (DCE) and non-direct contact evaporator (NDCE) types (21). In a DCE, the flue gas comes in contact with the black liquor, whereas in a NDCE, it does not. Field tests on five Kraft recovery furnaces showed $\text{SO}_3/\text{H}_2\text{SO}_4$ levels ranging from 0 to 3 ppm in the flue gas, with an average level of 0.81 ppm, or about 10% of that found in fossil fuel plants burning fuel containing 1-3% sulfur (4). In these tests, no correlation was found between SO_2 and $\text{SO}_3/\text{H}_2\text{SO}_4$ levels. Therefore, one cannot estimate emission factors for $\text{SO}_3/\text{H}_2\text{SO}_4$ based on those for SO_2 . While EPA has compiled emission factors for pollutants from kraft, acid sulfite, and neutral sulfite semichemical (NSSC) pulping (9), no emissions factors have been presented for $\text{SO}_3/\text{H}_2\text{SO}_4$. However, industry tests of Kraft recovery furnaces have been performed between 1989 and 1993 and the results are presented in Table 2 (20).

Table 2. Emission Factors from Kraft Recovery Furnaces *

Mill Code (date built/rebuilt)**: Control device/ Type evaporator	Type	BLS MPPD	H ₂ SO ₄ Emissions in lb/ton BLS	
			Range	Average
A: WB, Cascade	DCE	3.12	ND to 4.7E-02	1.6E-02
B: ESP	DCE	16.56	ND to 1.5E-02	8.4E-03
RFI (1973): WB ESP, Cascade	DCE		4.60 ND to 2.5E-02	1.4E-02
RFRIG1 (1991):WB ESP, Cyclone	DCE	0.85		ND(2.0E-02)
RFRIG2 (1991): WB ESP, Cyclone	DCE	2.63	ND to 1.9E-02	8.2E-03
SUMMARY	DCE		ND to 1.9E-02	8.4E-03 (Median)
C: DB	NDCE	9.84	0.21 to 0.91 ppm	3.3E-02
D: DB ESP	NDCE	18.60	0.17 to 2.98 ppm	7.1E-02
E: ESP	NDCE	12.00	0.49 to 1.71 ppm	5.1E-02
RFO (1986): DB ESP	NDCE	1.90		ND(1.3E-02)
SUMMARY	NDCE		ND to 1.6E-01	4.2E-02 (Median)

*Abbreviations: BLS = black liquor solids; ND = not detected; DCE = direct contact evaporator; NDCE = non-direct contact evaporator; ESP = electrostatic precipitator; WB = wet bottom; DB = dry bottom; MPPD = million pounds per day. Type evaporator given for DCE types only.

** Mills with codes not preceded by "RF" are from a 1980 study (4). Dates when these mills were built or rebuilt are not available.

The median sulfuric acid emissions from the direct contact (DCE) and non-direct contact (NDCE) evaporator recovery furnaces, $8.4\text{E-}03$ pounds per ton black liquor solids (BLS) and $4.2\text{E-}02$ pounds per ton BLS, respectively, can be used to estimate sulfuric acid emissions. For example, if a kraft mill using 1100 air dry tons of unbleached pulp per day (ADTUBPD) generates 3300 pounds BLS per ADTUBPD and operates two DCE furnaces 365 days per year, the pounds of H_2SO_4 , H, emitted during the year will be:

$$\text{H} = 1100 \text{ ADTUBPD} \times 365 \text{ days/year} \times (3300 \text{ lbs. BLS/ADTUBPD} \times \text{ton BLS/2000 lbs BLS}) \times 8.4\text{E-}03 \text{ lbs. H SO /ton BLS} = 5,565 \text{ lbs. of H}_2\text{SO}_4$$

The pounds of sulfuric acid aerosols produced in recovery furnaces on site should be combined with that produced from fuel oil and coal combustion. Should the total equal or exceed 25,000 pounds per year, reporting would be required under EPCRA Section 313. It should be noted that sulfuric acid used at the site for such purposes as ClO_2 generation, pH control, and ion exchange generation no longer must be reported since aerosol forms of H_2SO_4 are not involved.

Section 3.1.2 Acid Aerosols from Sulfuric Acid Manufacture

Sulfuric acid may be manufactured commercially by either the lead chamber process or the contact process. However, sulfuric acid is usually produced by the contact process (1, 2, 10, 22). In the contact process, sulfur is oxidized to SO_2 which is subsequently fed into a converter where it is catalytically oxidized to SO_3 . Finally, the sulfur trioxide is absorbed in a strong sulfuric acid solution or oleum. Sulfuric acid plants are further classified by feedstock: elemental sulfur burning, spent sulfuric acid and hydrogen sulfide burning, and metal sulfide ores and smelter gas burning. Contact sulfuric acid plants vary in design depending on the raw material used to produce SO_2 . Oleum is also produced in contact plants, where SO_3 -containing gases are passed through a special oleum tower. Regeneration of spent sulfuric acid is another form of sulfuric acid manufacture, often performed in order to comply with antipollution regulations (1).

Sulfuric Acid Manufacture

The amount of sulfuric acid aerosols produced in sulfuric acid manufacture is a function of the type of sulfur feedstock, the concentration of the absorbing acid, and the conditions in the absorber (1, 2, 22). Elemental sulfur produces little acid mist when burned because there is little water present. However the hydrocarbons in other feedstock (such as spent acid) produce water vapor during combustion. The affect of acid strength on mist production is illustrated by results showing 0.5 to 5.0 kilograms (kg) of uncontrolled acid aerosol emissions per Megagram (Mg) of acid produced (1.0 to 10.0 pounds (lb) of acid emissions per ton of acid produced) from oleum plants burning spent acid compared with 0.2 to 2.0 kg/Mg (0.4 to 4.0 lb/ton) of emissions from 98% sulfuric acid plants burning elemental sulfur. In addition, the aerosol particle size from oleum plants is finer than that from the 98% sulfuric acid plants. The operating temperature of the absorption tower affects SO_3 absorption and, accordingly, acid mist formed in the exit gas.

In an elemental sulfur burning plant, after the sulfur is burned to SO_2 and catalytically converted to SO_3 , the gas enters one or multiple absorption towers (packed columns), usually operated in countercurrent, in which the sulfur trioxide is absorbed in sulfuric acid of 98-99% concentration to form more sulfuric acid (1, 2, 22). The optimal operating temperature of the absorption tower depends on the strength of the acid produced, throughput rate, inlet sulfur trioxide concentrations and other factors peculiar to a particular plant. The optimal concentration of the absorbing acid is the azeotrope (see Appendix 1), 98.3%, where the combined vapor pressures of H_2SO_4 , SO_3 , and water are at a minimum. At lower concentrations, the water vapor partial pressure is higher and there is a greater risk of sulfuric acid mist formation. At higher concentrations the tail gas will contain increased amounts of H_2SO_4 and SO_3 because of their higher partial pressures. Both sulfuric acid mist formed within the system and gaseous sulfuric acid vaporized from the concentrated acid in the absorption towers and carried along with the predominant sulfur trioxide gas, constitute sulfuric acid aerosols that are being manufactured and therefore contributing to the manufacturing threshold of sulfuric acid aerosols for reporting under section 313 of EPCRA. Sulfuric acid mists entrained in tail gas are separated by special filters and determined by measurement of the acid content.

Regeneration of Spent Sulfuric Acid

The regeneration of spent sulfuric acid normally comprises two major steps, concentration to the highest feasible level and decomposition of the spent acid (1). Water is essentially the only substance evaporated (other than volatile organic impurities) in concentrating the acid to <75% H_2SO_4 . Vapors evolved during the concentration of spent sulfuric acid to a more highly concentrated state (93-98% H_2SO_4) contain significant quantities of gaseous sulfuric acid (1). The formation of this gaseous sulfuric acid contributes to the manufacturing threshold of sulfuric acid aerosols for reporting under section 313 of EPCRA. Spent sulfuric acid may be concentrated in either vacuum or drum concentrators. While vacuum concentrators yield negligible emissions, those from drum concentrators contain acid mist. Exit gas is passed through scrubbers before being vented to the atmosphere. Emissions from acid drum concentrators operating at 55, 73, and 100% of capacity are reported to be 7034, 2401, and 2334 metric ton/day (12).

Acid Aerosol Emissions

Nearly all the sulfuric acid aerosols emitted from sulfuric acid manufacturing plants come from the absorber exit gases. The exit gas contains small amounts of SO_2 , even smaller amounts of SO_3 , and sulfuric acid vapor and mist. Even with efficient gas drying, mist formation is impossible to eliminate completely. Once formed, these aerosols are of such a fine particle size and so stable that only a small amount can be removed in the absorber. Sulfuric acid is normally combined with SO_3 in determining an emission factor because SO_3 reacts so rapidly with water vapor. The emission factor for SO_3 is calculated as 100% H SO and added to the H_2SO_4 value.

Sulfuric acid mists are always formed when sulfur trioxide combines with water vapor at temperatures below the dew point of sulfur trioxide. The dew point is a function of gas composition and pressure and is generally around 140-170EC. Equations are available that predict the dewpoint for different concentrations of H_2O and H_2SO_4 (4). Examples are given in Section 3.1.5 in Tables 6 and 8 for coal and fuel oil combustion.

Use of Sulfuric Acid Emission Monitoring Data

Some sulfuric acid manufacturing facilities may have sulfuric acid emission monitoring data available that can be used to estimate emissions for sulfuric acid mist under the Clean Air Act New Source Performance Standards (NSPS). Sulfuric acid plants constructed or modified after August 17, 1971, are subject to a sulfuric acid mist emissions limit of 0.15 pounds of sulfuric acid per ton of 100% sulfuric acid produced (see Part 60 Subpart H of Title 40 of the Code of Federal Regulations). If such information is available, it is preferable to use such data for estimating uncontrolled emissions of sulfuric acid, rather than published emission factors since monitoring data should be the best available data. If the measured data available is for controlled emissions, then the amount of sulfuric acid generated prior to emission controls should be calculated based on the average actual control efficiency for the acid mist.

$$\text{Uncontrolled H}_2\text{SO}_4 \text{ emissions} = \text{actual emissions to air} / (1 - \text{efficiency})$$

(Efficiency expressed as a fraction)

Emission factors for sulfuric acid plants have been compiled by EPA (10). Uncontrolled emission factors for various sulfuric acid plants are shown in Table 3. Table 4 contains emission factors for plants using three of the most commonly used fiber mist eliminator control devices, vertical tube, vertical panel, and horizontal duel pad types.

Table 3. Uncontrolled Emission Factors for Sulfuric Acid Plants

Raw material	* Oleum produced % Total output	Emissions of H ₂ SO ₄ aerosol per unit product	
		kg/Mg	lb/ton
Recovered sulfur	0-43	0.174-0.4	0.348-0.8
Bright virgin sulfur	0	0.85	1.7
Dark virgin sulfur	0-100	0.16-3.14	0.32-6.28
Spent acid	0-77	1.1-1.2	2.2-2.4

*Sulfuric acid containing dissolved sulfur trioxide. Also known as fuming sulfuric acid or disulfuric acid.

Table 4. Controlled Emission Factors for Sulfuric Acid Plants

Raw material	* Oleum produced % Total output	Emissions of H ₂ SO ₄ aerosol per unit product	
		kg/Mg	lb/ton
Elemental sulfur	---	0.064	0.128
Dark virgin sulfur	0-13	0.26-1.8	0.52-3.6
Spent acid	0-56	0.014-0.20	0.28-0.40

*Sulfuric acid containing dissolved sulfur trioxide. Also known as fuming sulfuric acid or disulfuric acid.

Section 3.1.3. Smelters

Sulfuric acid is a byproduct of metals production, notably copper, and is accordingly sometimes referred to as smelter acid. Smelters produce sulfuric acid by the contact process with the raw material being classified as 'metal sulfide ores and smelter gas burning' (see Section 3.1.2). The smelter gas (SO_2 from the smelter furnace) is passed through cyclone dust collectors, electrostatic dust and mist precipitators, and scrubbing and gas cooling towers to remove dust, acid, mist and other impurities. The gas is then converted to SO_3 and then H_2SO_4 in processes similar to those used in sulfuric acid plants using elemental sulfur as a raw material (Section 3.1.2). Therefore, the potential for sulfuric acid aerosols formation is similar to the described above in the third paragraph of Section 3.1.2.

Section 3.1.4. Petroleum Refining

Crude oil contains a small amount of sulfur as an impurity. As a result, sulfur oxides are emitted from petroleum refineries. EPA has compiled emission factors of sulfur oxides, SO_x , for petroleum refining, but factors for sulfuric acid are not provided (11). However, according to information provided by the American Petroleum Institute (API), the staff in API's Health and Environmental Sciences Department uses the following EPA reference for sulfuric acid emission factors: EPA. 1995. Compilation of Air Pollutant Emission Factors. Vol. 1: Stationary Point and Area Sources. Section 8.10, AP-42, 5th ed. (January 1995). Research Triangle Park, NC: U.S. EPA, OAQPS.

Section 3.1.5. Sulfuric Acid Aerosol Formation In Stacks From Combustion Processes

Sulfuric acid aerosols are often formed in flue gas in a stack during combustion of fuel oil, coal, or other sulfur-containing fuels. Both water and sulfur trioxide are combustion products and they have great affinity for each other; as discussed they react quickly to form sulfuric acid. When flue gas is cooled to temperatures at or below the dew point, a sulfuric acid mist will form from any sulfuric acid gas present (16). The dew point is the temperature at which the air becomes saturated and produces dew; sulfuric acid mists are always formed when sulfur trioxide combines with water vapor at temperatures below the dew point of sulfur trioxide. Because of the enormous attraction between sulfur trioxide and water "only a very small amount of sulfur trioxide in combustion gas is required to draw water from the gas and form a fairly concentrated acid" (16). In fact, flue gas containing 1% sulfuric acid has the corrosive properties of 85% sulfuric acid solution. All sulfuric acid produced within the stack, including the gas not just the mist, falls under the EPCRA section 313 definition of a sulfuric acid aerosol. The information on dew points can be used to determine if any of the sulfuric acid present as gas will form a mist that could potentially condense inside the stack.

Tables 5 and 7 below contain expected sulfur trioxide levels in flue gas resulting from the combustion of fuel oil and coal, respectively, as a function of the sulfur content of the fuel and the percent of excess air available (16). If water is present in the stack, Tables 5 and 7 can be used to estimate the amount of sulfuric acid gas that can be formed. Tables 6 and 8 contain empirically-derived dew points of SO_3 for different concentrations of SO_3 in stack gas of oil- and coal-fired units, respectively. These tables can be used to determine whether the stack temperature is below the dew point of SO_3 and sulfuric acid mists are being formed in the stack

in flue gas. Examples of how to use these tables to determine the dew point of SO_3 are given below.

Assume a typical oil-fired unit is burning fuel oil containing 2% sulfur and that 17% excess air is present. From Table 5, we see that 15 ppm of SO_3 will be present in the flue gas and available to form sulfuric acid gas. From Table 6, we find that the dew point of SO_3 should be 139°C. Therefore, if the temperature in the stack is at or below 139°C, sulfuric acid mists will very likely form in the stack.

As an example dealing with coal combustion, assume a typical unit is burning coal containing 3% sulfur in the presence of 25% excess air. From Table 7, we see that between 20 and 40 ppm of SO_3 will be present in the flue gas and available to form sulfuric acid gas. From Table 8, we find that the dew point should be between 136°C and 143°C. Therefore, if the temperature in the stack is at or below 136°C to 143°C, sulfuric acid mists will very likely form in the stack.

Table 5. SO_3 Production in Oil Fired Units

Excess air (%)	SO_3 Concentration in Flue Gas (ppm)					
Sulfur in fuel (%)	0.5	1.0	2.0	3.0	4.0	5.0
5	2	3	3	4	5	6
11	6	7	8	10	12	14
17	10	13	15	19	22	25
25	12	15	18	22	26	30

Table 6. Dew Point of SO_3 in Stacks of Oil Fired Units*

SO in gas (ppm)	5	10	15	20	25	30	35	40	45	50	55	60	65	70
Dew point (°C)	130	135	139	141	143	145	147	148	149	150	151	152	153	154

*Using typical value of 10% water in oil

Table 7. SO_3 Production in Coal Fired Units

Excess air (%)	SO_3 Concentration in Flue Gas (ppm)					
Sulfur in fuel (%)	0.5	1.0	2.0	3.0	4.0	5.0
25	3-7	7-14	14-28	20-40	27-54	33-66

Table 8. Dew Point of SO_3 in Stacks of Coal Fired Units*

SO in gas (ppm)	5	10	15	20	25	30	35	40	45	50	55	60	65	70
Dew point (°C)	125	130	134	136	138	140	142	143	144	145	146	147	148	149

*Using typical value of 6% water in coal

Steel stacks are generally designed and operated so that a temperature between 135°C (275°F) and 149°C (300°F) is maintained throughout the stack (16). These stack temperatures are such that they may be below the dew point for SO₃ in the flue gas, leading to the formation of sulfuric acid mists in the stacks.

Section 3.1.6. Coal Combustion

Sulfuric acid aerosols are produced as a byproduct from boilers during coal combustion. U.S. coals contain from 0.2% to 7% sulfur by weight (13). On average, about 95% of sulfur present in bituminous coal will be emitted as gaseous sulfur oxides (SO_x) when burned, whereas somewhat less will be emitted when subbituminous coal is burned (15). In general, boiler size, firing configuration, and boiler operations have little effect on the percent conversion of sulfur in fuel to sulfur oxides. About 0.7% of fuel sulfur is emitted as SO₃/H₂SO₄ (15). This information can be expressed as an uncontrolled emission factor (EF) of $0.43 \times S$ pounds H₂SO₄ per ton of coal burned, where S is the weight percent sulfur in coal. The uncontrolled emission factor also represents the amount of sulfuric acid produced in the stack, as well as that released to the atmosphere in the absence of scrubbers or other emission control devices. The emission factor for sulfur oxides (SO_x) for bituminous coal combustion should not be used to estimate sulfuric acid emissions since the factor includes sulfur dioxide. If C is the tons of coal burned, the pounds of H₂SO₄ generated (H), would be:

$$H = 0.43 \times S \times C$$

For example, if 9,000 tons of coal were burned and the coal contained 3% sulfur, then:

$$H = 0.43 \times 3 \times 9,000 = 11,610 \text{ pounds of H}_2\text{SO}_4$$

Note that the values for the variables C and S have been chosen as an illustration. Values must be chosen that are appropriate for the particular operations at each facility.

Section 3.1.7. Fuel Oil Combustion

Sulfuric acid aerosols are produced during fuel oil combustion from the oxidation of sulfur contained in the fuel. There are various types of fuel oil combustion operations; the type of operation depends on the type of fuel oil burned. There are mainly five types of fuel oil used for commercial, industrial, and residential use in the U.S. The No. 1 and No. 2 fuel oils are known as distillate oils. They have high volatility, low viscosity, and <0.3% sulfur by weight. They are primarily used in domestic and small commercial operations. The No. 5 (also called low sulfur No. 6) and No. 6 fuel oils are known as residual oils. They have low volatility, high viscosity, and high sulfur content. They are mainly used in industrial operations. The No. 4 fuel oil is a mixture of distillate and residual oils and can be used for both types of operations. Typical sulfur contents of fuel oil are (13):

Fuel Oil Grade	Sulfur Content (wt %)
No. 1	0.09
No. 2	0.22
No. 4	1.35
No. 5	0.84
No. 6	3.97

Uncontrolled SO_x emissions are almost entirely dependent on the sulfur content of the fuel and are not affected by boiler size and design or the grade of fuel being burned. On the average, over 95% of the sulfur in fuel oil is converted to SO_2 on combustion; about 1 to 5 percent is further oxidized to sulfur trioxide where it readily reacts with water vapor in flue gas to form sulfuric acid aerosols. The emission factor ($^{\circ}\text{F}$) for uncontrolled fuel oil combustion from industrial boilers is $0.002 \times S$ pounds SO_3 per gallon of fuel oil burned (14) or $0.00245 \times S$ pounds H_2SO_4 per gallon of fuel oil burned, where S is the weight percent sulfur in the fuel oil. The uncontrolled emission factor also represents the amount of sulfuric acid produced in the stack, as well as that released to the atmosphere in the absence of scrubbers or other emission control devices. An example of the use of the emission factor ($^{\circ}\text{F}$) to calculate the pounds of sulfuric acid generated is shown below. If F is the number of gallons of fuel oil burned, the pounds of H_2SO_4 generated (H), would be:

$$H = 0.00245 \times S \times F$$

For example, if 4,500,000 gallons of fuel oil were burned and the fuel oil contained 3.97% sulfur, then:

$$H = 0.00245 \times 3.97 \times 4,500,000 = 43,769 \text{ pounds of } \text{H}_2\text{SO}_4$$

Note that the values for the variables F and S have been chosen as an illustration. Values must be chosen that are appropriate for the particular operations at each facility.

Section. 4.0. Measurement Methods

For source sampling, EPA has specified extractive sampling trains and analytical procedures for SO_3 and sulfuric acid aerosols (7, 8). Separation of particles containing Na_2SO_4 may present problems in cases such as Kraft paper mills (4). If sodium sulfate is present, analytical results for sulfuric acid would be high.

References

- (1) Muller H. 1994. Sulfuric Acid and Sulfur Trioxide. *Ullmann's Encyclopedia of Industrial Chemistry*, Vol A25, pp. 635-702.
- (2) Donovan JR, Salamone JM. 1983. Sulfuric Acid and Sulfur Trioxide. *Kirk Othmer Encyclopedia of Chemical Technology*, 3rd ed. Vol 22, pp. 190-232.
- (3) Calvert JG. 1984. *SO₂, NO and NO₂ Oxidation Mechanisms: Atmospheric Considerations*. Butterworth Publishers. pp. 1-62.
- (4) National Council for Air and Stream Improvement (NCASI). 1980. A Study of SO_x measurement procedures and their use at Kraft recovery furnaces. Atmospheric Quality Technical Bulletin No. 106, National Council for Air and Stream Improvement, New York, NY. April 17, 1980.
- (5) EPA. 1995. Sulfuric acid: Toxic chemical release reporting: Community right-to-know. Final rule. 60 FR 34182. June 30, 1995.
- (6) Wolff GT. 1991. Air pollution. *Kirk Othmer Encyclopedia of Chemical Technology*, 4th ed. Vol A1, pp. 725.
- (7) Crocker BB. 1991. Air pollution control methods. *Kirk Othmer Encyclopedia of Chemical Technology*, 4th ed. Vol 1, pp. 749-825.
- (8) EPA. 1975. Part 60 - Standards of performance for new stationary sources. Emission monitoring requirements and revisions to performance testing methods. 40 FR 46250 October 1975.
- (9) EPA. 1990. Compilation of Air Pollutant Emission Factors (AP-42). Wood Products Industry. Chemical Wood Pulp. 10.2-1 to 10.2-20. September, 1990. Research Triangle Park, NC: U.S. EPA, OAQPS.
- (10) EPA. 1993. Compilation of Air Pollutant Emission Factors (AP-42). Inorganic Chemical Industry. Sulfuric acid. 8.10-1 to 8.10-10. July, 1993. Research Triangle Park, NC: U.S. EPA, OAQPS.
- (11) EPA. 1993. Compilation of Air Pollutant Emission Factors (AP-42). Petroleum industry. Petroleum refining. 5.1-1 to 5.1-16. January, 1995. Research Triangle Park, NC: U.S. EPA, OAQPS.
- (12) Gerstle RW, Katari VS. 1977. Industrial Process Profiles for Environmental Use: Chapter 23. Sulfur, Sulfur Oxides and Sulfuric Acid. Prepared for Industrial Environmental Research Laboratory, Cincinnati, OH, Austin, TX: Radian Corporation. [NTIS PB-281 490]
- (13) Perry RH, Green DW. 1984. *Perry's Chemical Engineers' Handbook*, 6th Edition, pp. 3-68, 9-38 to 9-50. New York, NY: McGraw-Hill Book Company.

(14) EPA. 1995. Compilation of Air Pollutant Emission Factors (AP-42). Fuel Oil Combustion (AP-42). pp. 1.3-1 to 1.3-34. January 1995. Research Triangle Park, NC: U.S. EPA, OAQPS.

(15) EPA. 1995. Compilation of Air Pollutant Emission Factors (AP-42). Bituminous and Subbituminous Coal (AP-42). pp. 1.1-1 to 1.1-40. January 1995. Research Triangle Park, NC: U.S. EPA, OAQPS.

(16) Pierce R. 1977. Estimating acid dew points in stack gases. Chemical Engineering, April 11, 1997, vol. 89, pp. 125-128.

(17) Eatough DJ, Caka FM, Farber RJ. 1994. The conversion of SO_2 to sulfate in the atmosphere. Israel Journal of Chemistry 34: 301-314.

(18) EPA. 1982. Air Quality Criteria for Particulate Matter and Sulfur Oxides, Volume II, EPA-600/8-82-029b. Research Triangle Park, NC: U.S. EPA, Environmental Criteria and Assessment Office, pp. 2-1 to 2-100.

(19) EPA. 1988. Acid Aerosols Issue Paper. EPA-600/8-88-005a. Washington, D.C.: Office of Health and Environmental Assessment, pp. 2-1 to 2-74.

(20) National Council for Air and Stream Improvement (NCASI). 1995. Compilation of 'Air Toxic' and total hydrocarbon emission data for sources at chemical wood pulp mills. Volume 2. Technical Bulletin No. 701, National Council for Air and Stream Improvement, Research Triangle Park, NC. October 1995.

(21) National Council for Air and Stream Improvement (NCASI). 1996. Proceedings of the 1995 NCASI Southern Regional Meeting. Volume 2. Special Report No. 96-01, National Council for Air and Stream Improvement, Research Triangle Park, NC. October 1995. P. 326.

(22) Muller TL. 1992. Air Pollution Engineering Manual. Buonicore, AJ and Davis WT, eds, Van Nostrand Reinhold, New York., pp.469-476.

APPENDIX 1

Figure 1a. Boiling curves for sulfuric acid at 1013 mbar a)
Vapor; b) Liquid (reference 1).

Information in the above figure shows that if the vapor above a solution of 85% sulfuric acid, boiling at 223 °C, were to be completely condensed it would contain approximately 7 percent H₂SO₄. At concentrations below approximately 75% H₂SO₄, the vapor that evaporates from the solution is essentially water.

Table 1a. Sulfuric Acid Partial Pressure and Total Vapor Pressure (bar) over Aqueous Sulfuric Acid*

°F	Weight Percent Sulfuric Acid					
	20.0	40.0	60.0	80.0	98.0	0.0
32	.843E-20 (.534E-02)	.344E-17 (.326E-02)	.438E-14 (.836E-03)	.161E-10 (.197E-04)	.187E-08 (.117E-07)	.228E-08 (.323E-08)
68	.769E-18 (.205E-01)	.193E-15 (.130E-01)	.149E-12 (.367E-02)	.305E-09 (.115E-03)	.224E-07 (.121E-06)	.273E-07 (.435E-07)
104	.389E-16 (.649E-01)	.649E-14 (.427E-01)	.317E-11 (.131E-01)	.379E-08 (.531E-03)	.191E-06 (.914E-06)	.230E-06 (.425E-06)
140	.121E-14 (.175)	.144E-12 (.119)	.462E-10 (.395E-01)	.334E-07 (.204E-02)	.122E-05 (.538E-05)	.147E-05 (.319E-05)
176	.254E-13 (.417)	.225E-11 (.290)	.492E-09 (.104)	.222E-06 (.668E-02)	.622E-05 (.257E-04)	.743E-05 (.193E-04)
212	.381E-12 (.891)	.264E-10 (.634)	.402E-08 (.244)	.117E-05 (.192E-01)	.261E-04 (.103E-03)	.310E-04 (.966E-04)
302	.106E-09 (4.132)	.460E-08 (3.090)	.316E-06 (1.392)	.343E-04 (.170)	.493E-03 (.180E-02)	.574E-03 (.287E-02)
392	.883E-08 (13.107)	.278E-06 (10.245)	.975E-05 (5.312)	.457E-03 (.913)	.470E-02 (.166E-01)	.538E-02 (.427E-01)
482	.312E-06 (31.939)	.793E-05 (26.056)	.156E-03 (15.351)	.358E-02 (3.439)	.278E-01 (.985E-01)	.314E-01 (.389)
572	.591E-05 (64.407)	.130E-03 (54.869)	.156E-02 (36.361)	.266E-01 (9.916)	.117E-00 (.425)	.130E-00 (2.476)

* Total pressure is in parentheses. Conversion Factors: 1 bar = 0.98677 atmospheres = 14.7 psia = 760 mm Hg = 0.1 MPa

The above table contains the partial pressure of sulfuric acid and total vapor pressure of the solution (in parentheses) over aqueous sulfuric acid solutions in the concentration range of 20 to 100 weight percent sulfuric acid (1). From Table 1a we see that the partial pressure of sulfuric acid above a sulfuric acid solution is very low compared to the total vapor pressure for sulfuric acid solutions below 80% sulfuric acid; the bulk of the vapor being composed of water. Consequently when a solution of sulfuric acid boils, more water than sulfuric acid is volatilized, so that the concentration of the remaining acid increases and the boiling point of the solution rises. This process continues until the acid concentration reaches 98.3 weight % H_2SO_4 , when an azeotrope (a mixture of two liquids that boils at constant composition; i.e., the composition of the vapor is the same as that of the liquid) is formed and the concentration of sulfuric acid in the vapor is the same as that of the solution. The vapor above sulfuric acid solutions containing more than 98.3 weight % H_2SO_4 also includes considerable amounts of SO_3 , thus the difference between the partial pressure and total pressure of 100% sulfuric acid is the partial pressure of sulfur trioxide. Since the partial pressure of concentrated sulfuric acid is very low, little sulfuric acid is expected to volatilize from sulfuric acid solutions such as may be present in storage tanks. No experimental data are available on sulfuric acid aerosol emissions from storage tanks.

Above 340°C , H_2SO_4 decomposes into sulfur trioxide and water. The vapor-phase reaction of sulfur trioxide and water results in aerosols of sulfuric acid. The $\text{H}_2\text{SO}_4/\text{H}_2\text{O}/\text{SO}_3$ system is important in the production of sulfuric acid by the contact process as well as in the prevention of corrosion from condensing sulfuric acid in stack emissions from the combustion of sulfur-containing fuels. Sulfuric acid containing dissolved sulfur trioxide is known as oleum, fuming sulfuric acid or disulfuric acid. The vapor pressure of sulfuric acid over oleum containing 10% to 30% of free SO_3 by weight is shown in Table 2a (2). Since the vapor pressure of sulfur trioxide over oleum is high, sulfuric acid aerosols also form when oleum is exposed to air containing moisture.

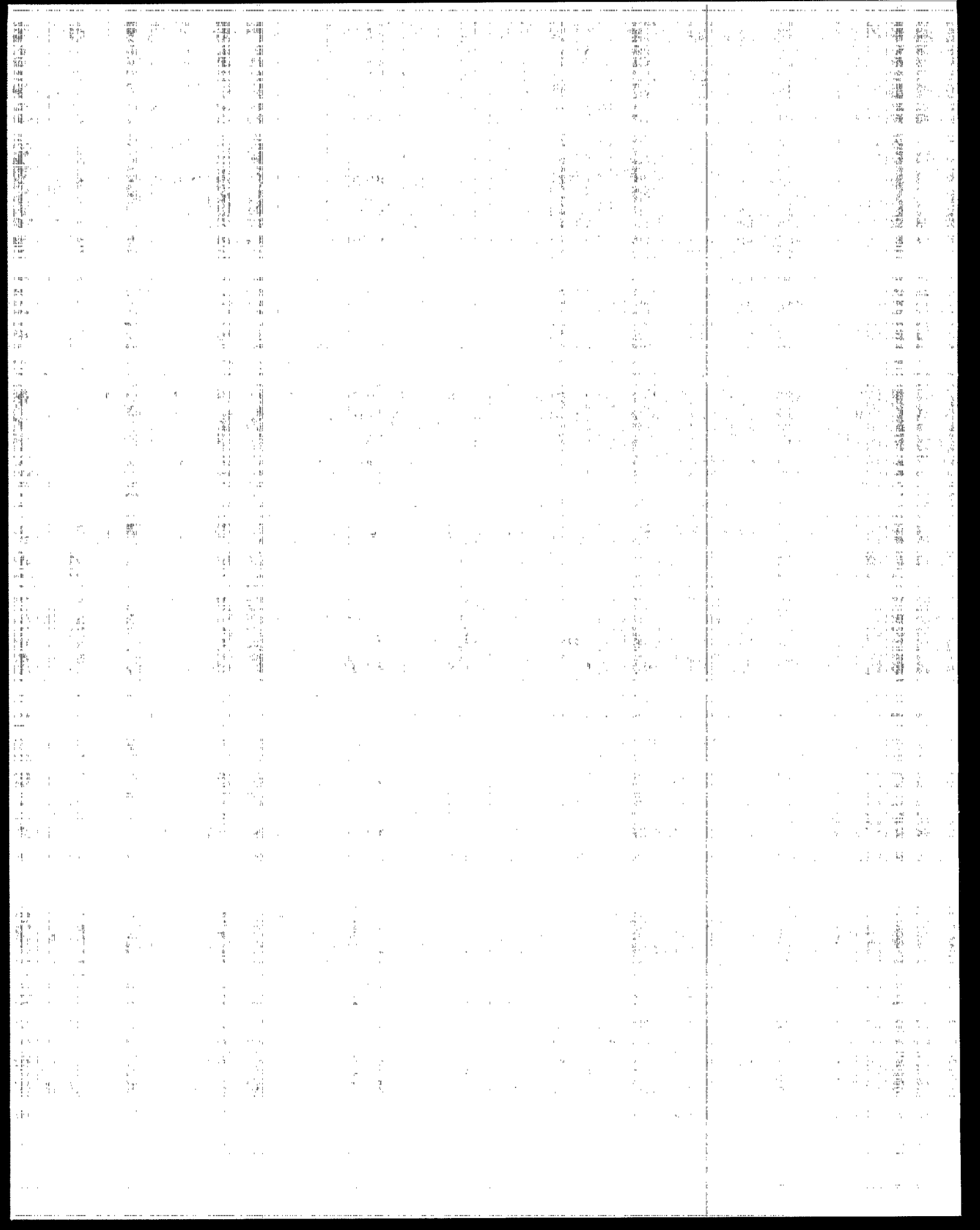
Table 2a. Sulfuric Acid Partial Pressure (bar) over Oleum *

$^\circ\text{C}$	Free SO_3 in oleum, %		
	10	20	30
20	.227 E-08	.120 E-08	.40 E-09
40	.1467 E-07	.667 E	-08 .267 E-08
60	.7333 E-07	.400 E-07	.1333 E-07
80	.3066 E-06	.1600 E-06	.600 E-07
100	.1067 E-05	.5333 E-06	.2133 E-06

Conversion Factors: 1 bar = 0.98677 atmospheres = 14.7 psia = 760 mm Hg = 0.1 Mpa;
 $^\circ\text{F} = 1.8 (^\circ\text{C}) + 32$.

Appendix E

LIST OF TOXIC CHEMICALS WITHIN THE WATER DISSOCIABLE NITRATE COMPOUNDS CATEGORY AND GUIDANCE FOR REPORTING





TOXICS RELEASE INVENTORY

List of Toxic Chemicals Within the Water Dissociable Nitrate Compounds Category and Guidance for Reporting

EPCRA Section 313 of the Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA) requires certain facilities manufacturing, processing, or otherwise using listed toxic chemicals to report their environmental releases of such chemicals annually. Beginning with the 1991 reporting year, such facilities also must report pollution prevention and recycling data for such chemicals, pursuant to section 6607 of the Pollution Prevention Act, 42 U.S.C. 13106. When enacted, EPCRA Section 313 established an initial list of toxic chemicals that was comprised of more than 300 chemicals and 20 chemical categories. EPCRA Section 313(d) authorizes EPA to add chemicals to or delete chemicals from the list, and sets forth criteria for these actions.

CONTENTS

Section 1.	Introduction	E-2
1.1	Who Must Report	E-2
1.2	Thresholds	E-2
1.3	Chemicals within the Water Dissociable Nitrate Compounds Category	E-3
1.4	<i>De Minimis</i> Concentrations	E-3
Section 2.	Guidance for Reporting Chemicals within the Water Dissociable Nitrate Compounds Category	E-4
2.1	Chemicals within the Water Dissociable Nitrate Compounds Category	E-4
2.2	Determining Threshold and Release Quantities for Nitrate Compounds	E-4
2.3	Reporting Nitrate Compounds Generated from the Partial or Complete Neutralization of Nitric Acid	E-5
2.3.1	Estimating Nitric Acid Releases	E-6
2.3.2	Estimating Treatment Efficiencies for Nitric Acid Neutralization	E-8
2.3.3	Estimating Releases of Nitrate Compounds Generated from the Neutralization of Nitric Acid	E-9
2.4	Generation of Nitrate Compounds from Biological Wastewater Treatment ..	E-10
Section 3.	CAS Number List of Some of the Individual Chemicals within the Water Dissociable Nitrate Compounds Category	E-11

Section 1. Introduction

On November 30, 1994 EPA added 286 chemicals and chemical categories, which include 39 chemicals as part of two delineated categories, to the list of toxic chemicals subject to reporting under EPCRA Section 313 of the Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA), 42 U.S.C. 11001. These additions are described at 59 FR 61432, and are effective January 1, 1995 for reports due July 1, 1996. Six chemical categories (nicotine and salts, strychnine and salts, polycyclic aromatic compounds, water dissociable nitrate compounds, diisocyanates, and polychlorinated alkanes) are included in these additions. At the time of the addition, EPA indicated that the Agency would develop, as appropriate, interpretations and guidance that the Agency determines are necessary to facilitate accurate reporting for these categories. This document constitutes such guidance for the water dissociable nitrate compounds category.

Section 1.1 Who Must Report

A plant, factory, or other facility is subject to the provisions of EPCRA Section 313, if it meets all three of the following criteria:

- It conducts manufacturing operations (is included in Standard Industrial Classification (SIC) codes 20 through 39); and
- It has 10 or more full-time employees (or the equivalent 20,000 hours per year); and
- It manufactures, imports, processes, or otherwise uses any of the toxic chemicals listed on the EPCRA Section 313 list in amounts greater than the "threshold" quantities specified below.

Section 1.2 Thresholds

Thresholds are specified amounts of toxic chemicals used during the calendar year that trigger reporting requirements.

If a facility *manufactures* or *imports* any of the listed toxic chemicals, the thresholds quantity will be:

- 25,000 pounds per toxic chemical or category over the calendar year.

If a facility *processes* any of the listed toxic chemicals, the threshold quantity will be:

- 25,000 pounds per toxic chemical or category over the calendar year.

If a facility *otherwise uses* any of the listed toxic chemicals (without incorporating it into any product or producing it at the facility), the threshold quantity is:

- 10,000 pounds per toxic chemical or category over the calendar year.

EPCRA Section 313 requires threshold determinations for chemical categories to be based on the total of all chemicals in the category manufactured, processed or otherwise used. For example, a facility that manufactures three members of a chemical category would count the total amount of all three chemicals manufactured towards the manufacturing threshold for that category. When filing reports for chemical categories, the releases are determined in the same manner as the thresholds. One report is filed for the category and all releases are reported on this form.

Section 1.3 Chemicals Within the Water Dissociable Nitrate Compounds Category

EPA is providing a list of CAS numbers and chemical names to aid the regulated community in determining whether they need to report for the water dissociable nitrate compounds category. The list includes individual chemicals within the water dissociable nitrate compounds category. If a facility is manufacturing, processing, or otherwise using a chemical which is on this list, they must report this chemical. However, this list is not exhaustive. If a facility is manufacturing, processing, or otherwise using a water dissociable nitrate compound, they must report the chemical, even if it does not appear on the list.

Section 1.4 *De Minimis* Concentrations

The water dissociable nitrate compounds category is subject to the one percent *de minimis* concentration. Thus, mixtures that contain members of this category in excess of the *de minimis* should be factored into threshold and release determinations.

Section 2. Guidance for Reporting Chemicals within the Water Dissociable Nitrate Compounds Category

Note: for the purposes of reporting under the nitrate compounds category, water dissociable means that the nitrate ion dissociates from its counterion when in solution.

Section 2.1 Chemicals within the Water Dissociable Nitrate Compounds Category

Chemicals within the nitrate compounds category are only reportable when in aqueous solution. All water dissociable nitrate compounds are included in the nitrate compounds category, including ammonium nitrate. Specifically listed EPCRA Section 313 chemicals *are not* included in threshold determinations for chemical categories such as the water dissociable nitrate compounds category. Specifically listed toxic chemicals are subject to their own individual threshold determinations. As of December 1, 1994, ammonium nitrate (solution) is not an individually listed chemical on the EPCRA Section 313 list. However, ammonium nitrate is still subject to reporting under the nitrate compounds category. In addition, the aqueous ammonia from the dissociation of ammonium nitrate when in aqueous solution is subject to reporting under the ammonia listing.

Section 2.2 Determining Threshold and Release Quantities for Nitrate Compounds

The total nitrate compound, including both the nitrate ion portion and the counterion, is included in the nitrate compounds category. When determining threshold amounts, the total weight of the nitrate compound is to be included in all calculations. However, only the nitrate ion portion is to be included when determining the amount of the chemicals within the nitrate compounds category that is released, transferred, or otherwise managed in wastes.

Example 1: In a calendar year, a facility processes 100,000 pounds of ammonium nitrate (NH_4NO_3), in aqueous solution, which is released to wastewater streams then transferred to a POTW. The quantity applied towards threshold calculations for the nitrate compounds category is the total quantity of the nitrate compound or 100,000 pounds. Since this quantity exceeds the 25,000 pound processing threshold, the facility is required to report for the nitrate compounds category. Under the nitrate compounds category, only the weight of the nitrate ion portion of ammonium nitrate is included in release transfer calculations. The molecular weight of the ammonium nitrate is 80.04 and the weight of the nitrate ion portion is 62.01 or 77.47 percent of the molecular weight of ammonium nitrate. Therefore, the amount of nitrate ion reported as transferred to the POTW is 77.47 percent of 100,000 pounds or 77,470 pounds (reported as 77,000 pounds). The aqueous ammonia from ammonium nitrate is reportable under the EPCRA Section 313 listing for ammonia. For determining thresholds and calculating releases under the ammonia listing, see the separate directive, *Guidance for Reporting Aqueous Ammonia* (EPA document #745-R-95-0003, July 1995).

Example 2: In a calendar year, a facility manufactures as by-products 20,000 pounds of sodium nitrate (NaNO_3) and 10,000 pounds of calcium nitrate ($\text{Ca}(\text{NO}_3)_2$), both in aqueous solutions, and releases these solutions to wastewater streams. The total quantity of nitrate compounds manufactured by the facility is the sum of the two chemicals, or 30,000 pounds, which exceeds the manufacturing threshold quantity of 25,000 pounds. The facility therefore is required to report for the nitrate compounds category. By weight, the nitrate ion portion is 72.96 percent of sodium nitrate and is 75.57 percent of calcium nitrate. Of the 20,000 pounds of the sodium nitrate in solution, 72.96 percent or 14,592 pounds is nitrate ion, and similarly, of the 10,000 pounds of the calcium nitrate in solution, 75.57 percent or 7,557 pounds is nitrate ion. The total nitrate ion in aqueous solution released by the facility is the sum of the nitrate ion in the two solutions or 22,149 pounds (reported as 22,000 pounds).

Section 2.3 Reporting Nitrate Compounds Generated from the Partial or Complete Neutralization of Nitric Acid

Nitric acid is an individually listed chemical on the original EPCRA Section 313 list and is reported as a separate chemical if the manufacture, process, or otherwise use thresholds are exceeded. The partial or complete neutralization of nitric acid results in the formation of nitrate compounds which are reported as chemicals within the nitrate compounds category if their manufacture, process, or otherwise use thresholds are exceeded.

Mineral acids such as nitric acid may be present in aqueous waste streams that are sent to on-site neutralization or are discharged to a publicly owned treatment works (POTW) or other off-site treatment facility. As stated in the *Toxic Chemical Release Inventory Reporting Form R and Instructions* document (revised 1993 version, EPA 745-K-94-001), on-site acid neutralization and its efficiency must be reported in Part II, section 7A of Form R (waste treatment methods and efficiency section). For purposes of reporting on Form R, EPA considers a waste mineral acid at a pH 6 or higher to be 100 percent neutralized (water discharges to receiving streams or POTWs are reported as zero). The nitrate compounds produced from the complete neutralization (pH 6.0 or above) of nitric acid are reportable under the nitrate compounds category and should be included in all threshold and release calculations. Two Form R reports would be required if the manufacture, process or otherwise use thresholds are exceeded for nitric acid and for the nitrate compounds category.

If the nitric acid treatment efficiency is not equal to 100 percent (pH is less than 6), the amount of the acid remaining in the waste stream which is released to the environment on-site or off-site must be reported in Part II of Form R. The nitrate compounds produced from the partial neutralization of nitric acid are reportable under the nitrate compounds category and should be included in all threshold and release calculations. Two reports would again be required if the manufacture, process or otherwise use thresholds are exceeded for nitric acid and for the nitrate compounds category.

Section 2.3.1 Estimating Nitric Acid Releases

The pH of the waste stream can be used to calculate the amount of nitric acid in the stream and the efficiency of neutralization. The pH is a measure of the acidity or alkalinity of a waste stream and can be obtained readily using a pH meter or pH sensitive paper. The pH scale itself varies from 0 to 14.

The total nitric acid concentration (ionized and un-ionized) in pounds per gallon can be calculated by using the pH value of the solution, the molecular weight and ionization constant of the acid, and appropriate conversion factors. The total acid concentration for nitric acid for different pH values is listed in Table 1. The calculation of mineral acid concentrations and the derivation of Table 1 are discussed in a separate directive, *Estimating Releases for Mineral Acid Discharges Using pH Measurements*, and an addendum to this directive.

The procedure outlined in this guidance document for calculating the quantity of nitrate compounds formed from the complete or partial neutralization of nitric acid can be used if nitric acid is the only mineral acid in a solution. In addition, the calculation of nitric acid releases using only pH measurements is a rough estimate. The subsequent calculation of nitrate compound releases is therefore also only a rough estimate. The estimates can be made for a waste stream with a steady pH below 6 or for one whose pH temporarily drops to below pH 6. Facilities should use their best engineering judgement and knowledge of the solution to evaluate how reasonable the estimates are.

Example 3: In a calendar year, a facility transfers 1.0 million gallons of a solution containing nitric acid (HNO_3), at pH 4, to a POTW. Using Table 1 (next page), a pH of 4 corresponds to a concentration of 0.0000520 lbs HNO_3 /gallon of solution. The weight of HNO_3 transferred can be estimated using the equation:

$$\text{Transfer of } \text{HNO}_3 = (\text{Concentration of } \text{HNO}_3) \times (\text{effluent flow rate})$$

Substituting the example values into the above equation yields:

$$\text{Transfer of } \text{HNO}_3 = 0.0000520 \text{ lbs/gal } \text{HNO}_3 \times 1,000,000 \text{ gal solution/year} = 52 \text{ lbs/year}$$

Example 4: A facility had an episodic release of nitric acid (HNO_3) in which the waste stream was temporarily below pH 6. During the episode, the wastewater (pH 2.0) was discharged to a river for 20 minutes at a rate of 100 gallons per minute. Using Table 1, a pH of 2.0 for HNO_3 represents a concentration of 0.0052000 lbs HNO_3 /gallon of solution. The amount of the HNO_3 released can be estimated using the following equation:

$$\text{Release of } \text{HNO}_3 = (\text{concentration of } \text{HNO}_3) \times (\text{effluent flow rate})$$

Substituting the example values in the above equation:

$$\begin{aligned} \text{Release of } \text{HNO}_3 &= 0.0052000 \text{ lbs/gal} \times 100 \text{ gal/min} \times 20 \text{ min} \\ &= 10 \text{ lbs} \end{aligned}$$

Table E-1
Nitric Acid Concentration Versus pH

pH	Nitric Acid Concentration (lbs/gallon)	pH	Nitric Acid Concentration (lbs/gallon)
0.0	0.5200000	3.0	0.0005200
0.2	0.3300000	3.2	0.0003300
0.4	0.2100000	3.4	0.0002100
0.6	0.1300000	3.6	0.0001300
0.8	0.0830000	3.8	0.0000830
1.0	0.0520000	4.0	0.0000520
1.2	0.0330000	4.2	0.0000330
1.4	0.0210000	4.4	0.0000210
1.6	0.0130000	4.6	0.0000130
1.8	0.0083000	4.8	0.0000083
2.0	0.0052000	5.0	0.0000052
2.2	0.0033000	5.2	0.0000033
2.4	0.0021000	5.4	0.0000021
2.6	0.0013000	5.6	0.0000013
2.8	0.0008300	5.8	0.0000008
		6.0	0.0000005

Section 2.3.2 Estimating Treatment Efficiencies for Nitric Acid Neutralization

Nitric acid solutions that are neutralized to a pH of 6 or above have a treatment efficiency of 100 percent. If nitric acid is neutralized to a pH less than 6, then the reportable treatment efficiency is somewhere between 0 and 100 percent. It is possible to estimate the neutralization treatment efficiency using nitric acid concentration values directly from Table 1 in the equation given below. The concentrations correspond to the pH values before and after treatment.

$$\text{Treatment efficiency} = \frac{(I - E)}{I} \times 100$$

where:

I = Acid concentration before treatment; and
E = Acid concentration after treatment.

Example 5: A nitric acid (HNO_3) waste stream of pH 2.4 is neutralized to pH 4.6. Using Table 1, the initial nitric acid concentration is 0.0021000 mol/liter and the final concentration is 0.0000130 mol/liter. Substituting these values into the equation for treatment efficiency:

$$\begin{aligned}\text{Treatment Efficiency} &= \frac{(0.0021000 - 0.0000130)}{0.0021000} \times 100 \\ &= 99.4 \text{ percent}\end{aligned}$$

For strong acids only (including nitric acid), the net difference in pH before and after treatment can be used to estimate the treatment efficiency since pH is directly proportional to the acid concentration. For example, a pH change of one unit results in a treatment efficiency of 90 percent, whether the pH change is from pH 1 to pH 2 or from pH 4 to pH 5. Table 2 summarizes treatment efficiencies for various pH changes (the pH change is the difference between the initial pH and the pH after neutralization). In the table, some pH changes result in the same treatment efficiency values due to rounding to one decimal place.

Table E-2
Nitric Acid Treatment Efficiencies for Various pH Changes

pH Unit Change	Treatment Efficiency (%)	pH Unit Change	Treatment Efficiency (%)
1.0	90.0	2.0	99.0
1.1	92.1	2.1	99.2
1.2	93.7	2.2	99.4
1.3	95.0	2.3	99.5
1.4	96.0	2.4	99.6
1.5	96.8	2.5	99.7
1.6	97.5	2.6	99.8
1.7	98.0	2.7	99.8
1.8	98.4	2.8	99.8
1.9	98.7	2.9	99.9
		3.0	99.9

Example 6: If a nitric acid (HNO_3) waste stream of pH 2 is treated to pH 4, the pH change is 2 units. Using Table 2 above, the treatment efficiency is given as 99.0 percent.

Section 2.3.3 Estimating Releases of Nitrate Compounds Generated from the Neutralization of Nitric Acid

The nitrate compounds produced from the complete neutralization (pH 6.0 or above) or partial neutralization (pH less than 6) or nitric acid are reportable under the nitrate compounds category if the appropriate threshold is met and should be included in all threshold and release calculations. In order to determine the quantity of a nitrate compound generated and released, the quantity of nitric acid released must be known (or calculated from the equations used in Examples 3 and 4 above) as well as the nitric acid treatment efficiency (calculated from the equations used in Examples 5 and 6 above).

The neutralization of nitric acid will most likely result in the generation of monovalent nitrate compounds (such as sodium nitrate and potassium nitrate). The quantity of these compounds formed in kilomoles will be equal to the quantity of the nitric acid neutralized in kilomoles. If divalent nitrate compounds are formed (such as calcium nitrate), the quantity of these compounds formed in kilomoles will be equal to one-half the quantity of the nitric acid neutralized in kilomoles. Similarly, if trivalent nitrate compounds are formed (such as iron (III) nitrate), the quantity formed of these compounds in kilomoles will be equal to one-third the quantity of the nitric acid neutralized in kilomoles. Note: to calculate the releases of nitrate compounds generated from the neutralization of nitric acid, the molecular weight of the nitrate compound formed must be used. Molecular weights of some of the individual chemicals within the water dissociable nitrate compounds category are given in Table 3.

Example 7: In a calendar year, a facility transfers 50,000 pounds of nitric acid (HNO_3) to an on-site treatment facility. The nitric acid treatment efficiency is 95 percent, and the nitrate compound formed as a result of the treatment is sodium nitrate (NaNO_3). The quantity of nitric acid transferred that is neutralized (generating sodium nitrate) is 95 percent of 50,000 pounds or 47,500 pounds. The molecular weight of nitric acid is 63.01 kg/kmol, and the molecular weight of sodium nitrate is 84.99 kg/kmol. The quantity of nitric acid neutralized is converted first to kilograms then to kilomoles using the following equations:

$$\text{Kilograms HNO}_3 \text{ neutralized} = (\text{lbs HNO}_3 \text{ neutralized}) \times (0.4536 \text{ kg/lb})$$

$$\text{Kilomoles HNO}_3 \text{ neutralized} = (\text{kg HNO}_3) \div (\text{MW of HNO}_3 \text{ in kg/kmol})$$

Substituting the example values into the above equation yields:

$$\text{Kilograms HNO}_3 \text{ neutralized} = 47,500 \text{ lbs} \times 0.4536 \text{ kg/lb} = 21,546 \text{ kg}$$

$$\text{Kilomoles HNO}_3 \text{ neutralized} = 21,546 \text{ kg} \div 63.01 \text{ kg/kmol} = 341.9 \text{ kmol}$$

The quantity of sodium nitrate generated in kilomoles is equal to the quantity of nitric acid neutralized (341.9 kmol). The quantity of sodium nitrate generated in kilomoles is converted first to kilograms then to pounds using the following equations:

$$\text{Kilograms NaNO}_3 \text{ generated} = (\text{kmol NaNO}_3) \times (\text{MW of NaNO}_3 \text{ in kg/kmol})$$

$$\text{Pounds NaNO}_3 \text{ generated} = (\text{kg NaNO}_3) \times (2.205 \text{ lbs/kg})$$

Substituting the values into the above equation yields:

$$\text{Kilograms NaNO}_3 \text{ generated} = 341.9 \text{ kmol} \times 84.99 \text{ kg/kmol} = 29,058 \text{ kg}$$

$$\text{Pounds NaNO}_3 \text{ generated} = 29,058 \text{ kg} \times 2.205 \text{ lbs/kg} = 64,073 \text{ pounds (reported as 64,000 pounds)}$$

The 64,000 pounds of sodium nitrate generated is the quantity used to determine whether thresholds have been met or exceeded. The quantity of nitrate ion released is calculated as in Example 1 above.

Section 2.4 Generation of Nitrate Compounds from Biological Wastewater Treatment

If a facility treats wastewater on-site biologically, using the activated sludge process, for example, the facility may be generating nitrate compounds as by-products of this biological process. The nitrate ion generated from this process will be associated with various counterions (e.g., sodium ion, potassium ion). In the absence of information on the identity of the counterion, a facility should assume for the purposes of EPCRA Section 313 threshold determinations that the counterion is sodium ion.

Section 3. CAS Number List of Some of the Individual Chemicals within the Water Dissociable Nitrate Compounds Category

EPA is providing the following table of CAS numbers and chemical names to aid the regulated community in determining whether they need to report for the water dissociable nitrate compounds category. If a facility is manufacturing, processing, or otherwise using a chemical which is listed below, they must report this chemical. However, this list is not exhaustive. If a facility is manufacturing, processing, or otherwise using a water dissociable nitrate compound, they must report this chemical, even if it does not appear on the following list.

Table E-3
Listing by CAS Number and Molecular Weight of Some of the Individual Chemicals within the Water Dissociable Nitrate Compounds Category

Chemical Name	Molecular Weight*	CAS Number
Aluminum nitrate, nonahydrate	213.00	7784-27-2
Ammonium nitrate	80.04	6484-52-2
Cerium (III) ammonium nitrate, tetrahydrate	486.22	13083-04-0
Cerium (IV) ammonium nitrate	548.23	10139-51-2
Barium nitrate	261.34	10022-31-8
Beryllium nitrate, trihydrate	133.02	7787-55-5
Cadmium nitrate	236.42	10325-94-7
Cadmium nitrate, tetrahydrate	236.42	10022-68-1
Calcium nitrate	164.09	10124-37-5
Calcium nitrate, tetrahydrate	164.09	13477-34-4
Cerium (III) nitrate, hexahydrate	326.13	10294-41-4
Cesium nitrate	194.91	7789-18-6
Chromium (III) nitrate, nonahydrate	238.01	7789-02-8
Cobalt (II) nitrate, hexahydrate	182.94	10026-22-9
Copper (II) nitrate, trihydrate	187.56	10031-43-3
Copper (II) nitrate, hexahydrate	187.56	13478-38-1
Dysprosium (III) nitrate, pentahydrate	348.51	10031-49-9
Erbium (III) nitrate, pentahydrate	353.27	10031-51-3
Gadolinium (III) nitrate, hexahydrate	343.26	19598-90-4
Gallium nitrate, hydrate	255.73	69365-72-6
Iron (III) nitrate, hexahydrate	241.86	13476-08-9
Iron (III) nitrate, nonahydrate	241.86	7782-61-8

Table E-3 (Continued)

Chemical Name	Molecular Weight*	CAS Number
Lanthanum (III) nitrate, hexahydrate	324.92	10277-43-7
Lead (II) nitrate	331.21	10099-74-8
Lithium nitrate	68.95	7790-69-4
Lithium nitrate, trihydrate	68.95	13453-76-4
Magnesium nitrate, dihydrate	148.31	15750-45-5
Magnesium nitrate, hexahydrate	148.31	13446-18-9
Manganese (II) nitrate, tetrahydrate	178.95	20694-39-7
Neodymium (III) nitrate, hexahydrate	330.25	16454-60-7
Nickel (II) nitrate, hexahydrate	182.70	13478-00-7
Potassium nitrate	101.10	7757-79-1
Rhodium (III) nitrate, dihydrate	288.92	13465-43-5
Rubidium nitrate	147.47	13126-12-0
Samarium (III) nitrate, hexahydrate	336.37	13759-83-6
Scandium (III) nitrate	230.97	13465-60-6
Scandium (III) nitrate, tetrahydrate	230.97	16999-44-3
Silver nitrate	169.87	7761-88-8
Sodium nitrate	84.99	7631-99-4
Strontium nitrate	211.63	10042-76-9
Strontium nitrate, tetrahydrate	211.63	13470-05-8
Terbium (III) nitrate, hexahydrate	344.94	13451-19-9
Thorium (IV) nitrate	480.06	13823-29-5
Thorium (IV) nitrate, tetrahydrate	480.06	13470-07-0
Yttrium (III) nitrate, hexahydrate	274.92	13494-98-9
Yttrium (III) nitrate, tetrahydrate	274.92	13773-69-8
Zinc nitrate, trihydrate	189.39	131446-84-9
Zinc nitrate, hexahydrate	189.39	10196-18-6
Zirconium (IV) nitrate, pentahydrate	339.24	13986-27-1

*For hydrated compounds, e.g., aluminum nitrate, nonahydrate, the molecular weight excludes the weight of the hydrate portion. For example, the same molecular weight is provided for aluminum nitrate, nonahydrate and aluminum nitrate.

Appendix F

UNIT CONVERSION FACTORS

(From U.S. Coast Guard Commandant Instruction M.16465.12A)

1. 材料費	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	100
--------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-----

CONVERSION FACTORS

To Convert	To	Multiply By
Length		
inches	millimeters	25.4
inches	feet	0.0833
feet	inches	12
feet	meters	0.3048
feet	yards	0.3333
feet	miles (U.S. statute)	0.0001894
yards	feet	3
yards	miles (U.S. statute)	0.0005682
miles (U.S. statute)	feet	5280
miles (U.S. statute)	yards	1760
miles (U.S. statute)	meters	1609
miles (U.S. statute)	nautical miles	0.868
meters	feet	3.271
meters	yards	1.094
meters	miles (U.S. statute)	0.0006214
nautical miles	miles (U.S. statute)	1.152
Area		
square inches	square centimeters	6.452
square inches	square feet	0.006944
square feet	square inches	144
square feet	square meters	0.09290
square meters	square feet	10.76
square miles	square yards	3,097,600
square yards	square feet	9
Volume		
cubic inches	cubic centimeters	16.39
cubic inches	cubic feet	0.0005787
cubic feet	cubic inches	1728
cubic feet	cubic meters	0.02832
cubic feet	U.S. gallons	7.481
cubic meters	cubic feet	35.31
liters	quarts (U.S. liquid)	1.057
quarts (U.S. liquid)	liters	0.9463
U.S. gallons	barrels (petroleum)	0.02381
U.S. gallons	cubic feet	0.1337
U.S. gallons	Imperial gallons	0.8327
barrels (petroleum)	U.S. gallons	42
Imperial gallons	U.S. gallons	1.201
milliliters	cubic centimeters	1

CONVERSION FACTORS (Continued)

To Convert

To

Multiply By

Time

seconds

minutes

0.01667

seconds

hours

0.0002778

seconds

days

0.00001157

minutes

seconds

60

minutes

hours

0.01667

minutes

days

0.0006944

hours

seconds

3600

hours

minutes

60

hours

days

0.04167

Mass or Weight

pounds

kilograms

0.4536

pounds

short tons

0.0005

pounds

long tons

0.000464

pounds

metric tons

0.0004536

tons (short)

pounds

2000

tons (metric)

pounds

2205

tons (long)

pounds

2240

kilograms

pounds

2.205

tonnes (metric tons)

kilograms

1000

Energy

calories

Btu

0.003968

calories

joules

4.187

Btu (British thermal units)

calories

252.0

Btu

joules

1055

joules

calories

0.2388

joules

Btu

0.0009479

Velocity

feet per second

meters per second

0.3048

feet per second

miles per hour

0.6818

feet per second

knots

0.5921

meters per second

feet per second

3.281

meters per second

miles per hour

2.237

miles per hour

meters per second

0.4470

miles per hour

feet per second

1.467

knots

meters per second

0.5148

knots

miles per hour

1.151

knots

feet per second

1.689

pounds per cubic foot

grams per cubic centimeter

0.01602

grams per cubic centimeter

pounds per cubic foot

62.42

grams per cubic centimeter

kilograms per cubic meter

1000

kilograms per cubic meter

grams per cubic centimeter

0.001

CONVERSION FACTORS (Continued)

To Convert	To	Multiply By
Pressure		
ponds per square inch (absolute) (psia)	kilonewtons per square meter (kN/m^2)	6.895
psia	atmospheres	0.0680
psia	inches of water	27.67
psia	millimeters of mercury (torr)	51.72
pounds per square inch (gauge) (psig)	psia	add 14.70
millimeters of mercury (torr)	psia	0.01934
millimeters of mercury (torr)	kN/m^2	0.1333
inches of water	psia	0.03614
kilograms per square centimeter	millimeters of mercury (torr)	735.6
inches of water	kN/m^2	0.2491
kilograms per square centimeter	atmospheres	0.9678
atmospheres	kN/m^2	101.3
kilograms per square centimeter	psia	14.22
atmospheres	psia	14.70
bars	kN/m^2	100
kilonewtons per square meter (kN/m^2)	psia	0.1450
bars	atmospheres	0.9869
kilonewtons per square meter (kN/m^2)	atmospheres	0.009869
bars	kilograms per square centimeter	1.020
Viscosity		
centipoises	pounds per foot per second	0.0006720
pounds per foot per second	centipoises	1488
centipoises	poises	0.01
centipoises	Newton seconds per square meter	0.001
poises	grams per centimeter per second	1
grams per centimeter per second	poises	1
Newton seconds per square meter	centipoises	1000
Thermal Conductivity		
Btu per hour per foot per $^{\circ}\text{F}$	watts per meter-kelvin	1.731
Btu per hour per foot per $^{\circ}\text{F}$	kilocalories per hour per meter per $^{\circ}\text{C}$	1.488
watts per meter-kelvin	Btu per hour per foot per $^{\circ}\text{F}$	0.5778
kilocalories per hour per meter per $^{\circ}\text{C}$	watts per meter-kelvin	1.163
kilocalories per hour per meter per $^{\circ}\text{C}$	Btu per hour per foot per $^{\circ}\text{F}$	0.6720
Heat Capacity		
Btu per pound per $^{\circ}\text{F}$	calories per gram per $^{\circ}\text{C}$	1
Btu per pound per $^{\circ}\text{F}$	joules per kilogram-kelvin	4187
joules per kilogram-kelvin	Btu per pound per $^{\circ}\text{F}$	0.0002388
calories per gram per $^{\circ}\text{C}$	Btu per pound per $^{\circ}\text{F}$	1

CONVERSION FACTORS (Continued)

To Convert

To

Multiply By

Concentration (in water solution)

parts per million (ppm)

milligrams per liter

1

milligrams per liter

ppm

1

milligrams per cubic meter

grams per cubic centimeter

1×10^{-9}

grams per cubic centimeter

milligrams per cubic meter

1×10^9

grams per cubic centimeter

pounds per cubic foot

62.42

pounds per cubic foot

grams per cubic centimeter

0.01602

Temperature

degrees Kelvin ($^{\circ}\text{K}$)

degrees Rankine ($^{\circ}\text{R}$)

1.8

degrees Rankine ($^{\circ}\text{R}$)

degrees Kelvin ($^{\circ}\text{K}$)

0.5556

degrees centigrade ($^{\circ}\text{C}$)

degrees Fahrenheit ($^{\circ}\text{F}$)

first multiply by 1.8, then add 32

degrees Fahrenheit ($^{\circ}\text{F}$)

degrees centigrade ($^{\circ}\text{C}$)

first subtract 32, then multiply by

0.5556

degrees centigrade ($^{\circ}\text{C}$)

degrees Kelvin ($^{\circ}\text{K}$)

add 273.2

degrees Fahrenheit ($^{\circ}\text{F}$)

degrees Kelvin ($^{\circ}\text{K}$)

add 459.7

Flow

cubic feet per second

U.S. gallons per minute

448.9

U.S. gallons per minute

cubic feet per second

0.002228

Universal Gas Constant (R)

8.314 joules per gram mole-kelvin

1.987 calories per gram mole-kelvin

1.987 Btu per pound mole per $^{\circ}\text{F}$

10.73 psia-cubic feet per pound mole per $^{\circ}\text{F}$

82.057 atm-cubic centimeters per gram mole-kelvin

62.361 millimeters mercury liter per gram mole-kelvin

INDEX

The pages listed in bold text in the index correspond to the primary uses or definitions of the associated term. Additionally, this index includes a list of primary purposes for examples and common errors that are presented throughout the document.

Acid aerosol (<i>see Sulfuric acid and Hydrochloric acid</i>)	3-5, 3-7
Common error, acid aerosol reporting	4-40
Activity	
Chemical use, subcategories	3-7 to 3-12
Exemption (<i>see Exemptions</i>)	
Thresholds (<i>see Threshold</i>)	
Air emissions	
Fugitive or non-point	4-4 , 4-20, 4-25, 4-33, 4-34, 4-38, 4-42, 4-45, 4-48
Stack or point source	4-5 , 4-22, 4-24, 4-25, 4-34, 4-35, 4-38, 4-39, 4-42, 4-43, 4-45, 4-51
Article exemption (<i>see Exemptions</i>)	
Automated toxic chemical release inventory software (ATRS)	2-11
Chemical-specific	
Acid aerosols	3-5, 3-7, 4-40
Ammonia	2-8, 2-9, 3-6 , 3-18, 4-19, 4-36 to 4-39, 4-45, 4-46, Appendix C
Chlorine	3-11, 4-19, 4-31, 4-36, 4-37, 4-39, 4-40, 4-50, 4-51
Hydrochloric acid	2-8, 2-10, 3-5 , 3-15, 4-31, 4-33, 4-34, 4-40, 4-42, 4-45
Methanol	2-8, 3-11, 3-18, 4-33, 4-34, 4-45, 4-47
Nitrate compounds	2-8, 2-9, 3-6 , 3-9, 4-41 to 4-43, 4-53, Appendix E
Sulfuric acid	2-8, 3-6, 3-7 , 3-9, 3-17, 4-33, 4-34, 4-40, 4-42, 4-45, Appendix D
Chemical mechanical planarization	2-8, 4-29, 4-51 to 4-53
Chemical processing aid	3-11
Cleaning	2-8, 2-10, 3-9, 3-11, 3-17, 4-7 , 4-24, 4-32, 4-43
Combustion	3-15, 3-18, 3-19, 4-3, 4-10, 4-12 to 4-14, 4-23
For energy recovery off-site	4-13 to 4-14
For energy recovery on-site	4-12
For treatment off-site	4-15
For treatment on-site	4-10
Common errors	
Acid aerosol reporting	4-40
Assuming a threshold is exceeded	3-22
Coincidental manufacture	2-10
Double counting	4-16
Exempt activities	3-12
Mass balance	4-21
Nitric acid and nitrate compound reporting	4-41
Shipping container residue	4-8, 4-10
Solvent reporting	4-32
Threshold determination for recirculation	3-8
Treatment efficiencies	4-19

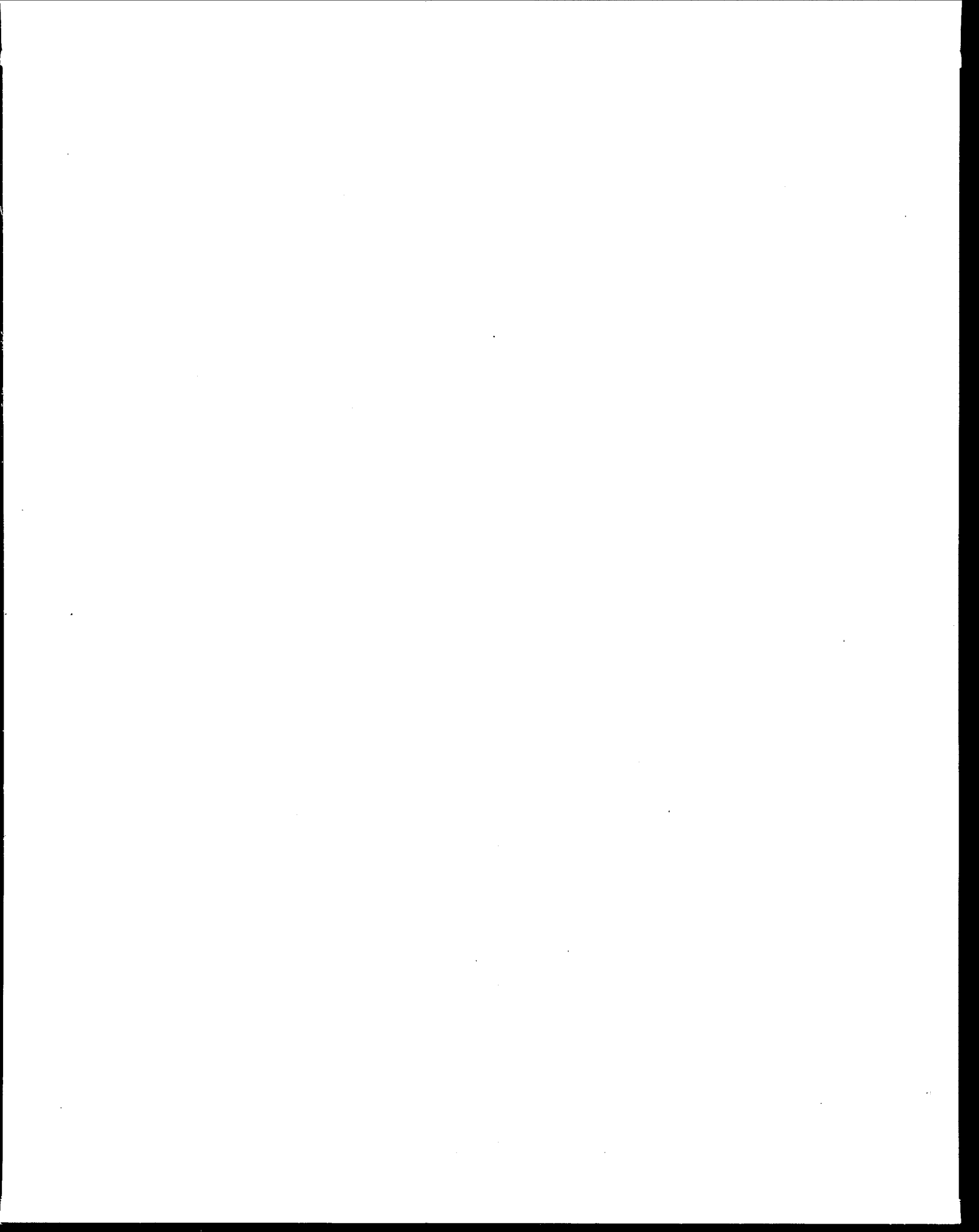
Zero release and other waste management quantities	3-22
Container residue	4-8 to 4-10, 4-45, 4-49, 4-56
Example, container residue	4-10
<i>De minimis (see Exemptions)</i>	
Example, <i>de minimis</i>	3-13
Example, <i>de minimis</i> concentration ranges	3-14
Disposal	2-9, 3-9, 4-12
Land, on-site	4-6 to 4-8
Land, off-site	4-7, 4-12 to 4-15, 4-33, 4-38
Documentation (<i>see Recordkeeping</i>)	
Doping	2-8, 4-29, 4-48 to 4-51
Double counting	4-6, 4-16
Common error, double counting	4-16
Emission factors	4-17, 4-18, 4-21 to 4-23, B-6
Example, emission factors	4-23, B-6
Employee equivalent calculation	2-7 to 2-8
Example, calculating employees	2-2
Energy recovery (<i>see Combustion for energy recovery</i>)	
Engineering calculation	4-17, 4-18, 4-21, 4-23, 4-24, 4-39, 4-48, 4-51, B-1
Example, engineering calculations	4-24
EPCRA hotline	1-2, 1-3, 1-5, 2-7, 2-11
Establishment	2-1, 2-5
Example, multiple establishments	2-2
Example, primary SIC code	2-7
Etching	2-8, 2-10, 3-9, 3-11, 3-17, 4-29, 4-31, 4-39 to 4-43
Examples	
Article exemption	3-17
Chemicals in process water	3-19
Chemical mechanical planarization	4-53
Cleaning	4-46 and 4-47
Container residue	4-10
<i>De minimis</i>	3-13
<i>De minimis</i> concentration ranges	3-14
Doping	4-51
Emission factors	4-23, B-6
Employee equivalent calculation	2-7
Engineering calculation	4-24
Etching	4-43
Form A threshold	2-12
Mass balance	4-20, 4-21
Monitoring data	4-19
Motor vehicle exemption	3-18
Multiple establishments	2-2
On-site waste treatment	4-11
Personal use exemption	3-18
Photolithography	4-35
Process equipment chemical use	3-19

Relabeling	2-10
Thin films	4-39
Threshold determination	3-8
Threshold worksheet	3-23
Exempt activities	3-1, 3-7, 3-12, 3-18
Common error, exempt activities	3-12
Exemptions	3-12
Activity-related	3-12, 3-17
Article	3-12, 3-15
<i>De minimis</i>	3-12 to 3-15, D-3, E-3
Drawn from environment	3-19
Evaluation of	3-12
Facility-related	3-17
Grounds maintenance	3-17
Janitorial	3-17
Laboratory	2-5, 3-17
Motor vehicle	3-18
Personal use, example	3-18
Structural components	3-18
Facility	
Auxiliary facility	2-5
Covered facility	2-5, 2-14
Multi-establishment facilities (<i>see Establishments</i>)	
Pilot plant	2-5, 3-17
Facility-related exemption (<i>see Exemption</i>)	
Form A	1-3 to 1-5, 2-1, 2-2, 2-12 to 2-14, 3-20
Example Form A threshold	2-12
Form R	1-3 to 1-5, 2-2, 2-10 to 2-13, 3-20, 4-4 to 4-16, 4-25, 4-26, 4-28, 4-39, 4-47, 4-52, 4-53, 4-58, 4-59
Impurity	2-9, 3-9, 3-13
Laboratory exemption (<i>see Exemption</i>)	
Manufacture/Manufacturing	2-9, 3-5, 3-9
Byproduct	3-9
Coincidental manufacture	3-18, 4-41, 4-42
Manufacturing subcategories	3-9
Mass balance	4-17 to 4-21, 4-34, 4-39, 4-48
Example, mass balance	4-20, 4-21
Methods (<i>see Reportable amount estimate methods</i>)	
Mineral acids	4-43
Mixture	2-10, 3-1 to 3-3, 3-9 to 3-11, 3-14, 3-23
Monitoring data	4-18 to 4-20, 4-51, 4-57, B-1
Example, monitoring data	4-19
Motor vehicle exemption (<i>see Exemption</i>)	
MSDS	3-4, 3-11
Otherwise use	2-7, 2-19, 3-11
Common error, mass balance for otherwise used chemicals	4-21
Owner/operator	1-3

Penalties	1-4
Photolithography	2-8, 4-29, 4-31 to 4-33, 4-35, 4-52
Pilot plant (<i>see Facility</i>)	
Point source (<i>see Air emissions</i>)	
POTW	4-7, 4-10, 4-11, 4-15, 4-16, 4-18, 4-19, 4-27, 4-33 to 4-35, 4-38, 4-39, 4-41 to 4-43, 4-45, 4-46, 4-51, 4-53
Process/processing	2-9, 3-10
Process equipment	3-17, 3-18
Example, process equipment chemical use	3-19
Process water	3-19
Example, chemicals in process water	3-19
Processing subcategories	3-10
Qualifiers	3-4
Recordkeeping	2-14
Recycling	3-8, 3-21, 4-31, 4-32
Off-site	4-14
On-site	4-14
Relabeling, example	2-10
Release	Chapter 4
Accidental	4-15
Estimates (steps to calculate)	4-1, 4-16
Sources	4-3, 4-33, 4-37, 4-41, 4-44, 4-50, 4-52
Types	4-4, 4-33, 4-38, 4-42, 4-50, 4-53
Remedial actions	3-20, 4-15
Remediation	3-20, 4-16
Repackaging	2-10, 3-10
Reportable amount	2-12
Reportable amount estimate methods	1-4, 2-12
Emission factors	4-21
Engineering calculations	4-23
Mass balance	4-19
Monitoring data/records	4-18
Reporting criteria	2-1
Reuse	3-8, 3-19
Sources (<i>see Release</i>)	
Standard Industrial Classification (SIC)	2-4 to 2-7
Primary SIC code	2-6, 2-7
Technically qualified individual	3-17
Thin films	2-8, 4-29, 4-36 to 4-39
Threshold worksheet	3-22 to 3-24
Thresholds	3-8
Common error, threshold determination	3-8
Example, threshold determination	3-8
Threshold determination	Chapter 3, 3-21
Threshold worksheet	3-22
Total annual reportable amount (<i>see Reportable amount</i>)	
Trade secret	1-4, 2-13

Transfers	4-7, 4-13 to 4-16, 4-20, 4-33, 4-42, 4-45
Treatment efficiency	4-10, 4-11, 4-19
Treatment for destruction	
On-site	4-10 to 4-15
Off-site	4-15 to 4-16
Types (<i>see Release</i>)	
Waste management	Chapter 4
Waste treatment (<i>see Treatment for destruction</i>)	
Common error, treatment efficiencies	4-19
Example, on-site waste treatment	4-11
Wastewater discharge	4-6
Wastewater treatment	4-7, 4-11, 4-19 to 4-20, 4-41, 4-43, 4-50

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200
201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300
301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400
401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460	461	462	463	464	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480	481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500
501	502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	517	518	519	520	521	522	523	524	525	526	527	528	529	530	531	532	533	534	535	536	537	538	539	540	541	542	543	544	545	546	547	548	549	550	551	552	553	554	555	556	557	558	559	560	561	562	563	564	565	566	567	568	569	570	571	572	573	574	575	576	577	578	579	580	581	582	583	584	585	586	587	588	589	590	591	592	593	594	595	596	597	598	599	600
601	602	603	604	605	606	607	608	609	610	611	612	613	614	615	616	617	618	619	620	621	622	623	624	625	626	627	628	629	630	631	632	633	634	635	636	637	638	639	640	641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664	665	666	667	668	669	670	671	672	673	674	675	676	677	678	679	680	681	682	683	684	685	686	687	688	689	690	691	692	693	694	695	696	697	698	699	700
701	702	703	704	705	706	707	708	709	710	711	712	713	714	715	716	717	718	719	720	721	722	723	724	725	726	727	728	729	730	731	732	733	734	735	736	737	738	739	740	741	742	743	744	745	746	747	748	749	750	751	752	753	754	755	756	757	758	759	760	761	762	763	764	765	766	767	768	769	770	771	772	773	774	775	776	777	778	779	780	781	782	783	784	785	786	787	788	789	790	791	792	793	794	795	796	797	798	799	800
801	802	803	804	805	806	807	808	809	810	811	812	813	814	815	816	817	818	819	820	821	822	823	824	825	826	827	828	829	830	831	832	833	834	835	836	837	838	839	840	841	842	843	844	845	846	847	848	849	850	851	852	853	854	855	856	857	858	859	860	861	862	863	864	865	866	867	868	869	870	871	872	873	874	875	876	877	878	879	880	881	882	883	884	885	886	887	888	889	890	891	892	893	894	895	896	897	898	899	900
901	902	903	904	905	906	907	908	909	910	911	912	913	914	915	916	917	918	919	920	921	922	923	924	925	926	927	928	929	930	931	932	933	934	935	936	937	938	939	940	941	942	943	944	945	946	947	948	949	950	951	952	953	954	955	956	957	958	959	960	961	962	963	964	965	966	967	968	969	970	971	972	973	974	975	976	977	978	979	980	981	982	983	984	985	986	987	988	989	990	991	992	993	994	995	996	997	998	999	1000





United States
Environmental Protection Agency
(7408)
Washington, DC 20460

Official Business
Penalty for Private Use
\$300